

190

SUMMARY

SATURN S-IVB STAGE
WEIGHT CONTROL STATUS REPORT

MODEL NO. DSV-4B

DOUGLAS REPORT DAC-56392
JULY 1966

PREPARED BY:
WEIGHT CONTROL SECTION
SATURN ENGINEERING

PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101

A. P. O'Neal

APPROVED BY: A. P. O'NEAL
DIRECTOR, SATURN DEVELOPMENT ENGINEERING

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER - HUNTINGTON BEACH, CALIFORNIA

FACILITY FORM 602

N70-76309

(ACCESSION NUMBER)

78

(PAGES)

CR 113298

(NASA CR OR TMX OR AD NUMBER)

(THRU)

None

(CODE)

(CATEGORY)

ABSTRACT

This report summarizes the achievements of two years of weight reduction and performance improvement efforts on the Saturn S-IVB Stage, which resulted in Saturn payload capability improvements of more than 5000 pounds on the Saturn IB and more than 6000 pounds on the Saturn V.

DESCRIPTORS

Weight Control	Weight Consciousness
Flight Performance	Weight Reduction

PREFACE

The purpose of this report is to summarize the results of the Saturn S-IVB augmented Weight Control Program. This is the twenty-first and last report of this type to be prepared in compliance with Supplemental Agreement 570 to Contract NAS7-101.

TABLE OF CONTENTS

Paragraph		Page
	<u>SECTION I</u>	
1.	INTRODUCTION AND SUMMARY	1
1.1	The Teamwork Approach	1
1.2	Highlights of DAC Implemented Changes	2
1.3	Highlights of MSFC Directed Changes	2
1.4	Weight Consciousness Program	2
1.5	Weight Reduction Study Effort	3
	<u>SECTION II</u>	
2.	WEIGHT CONSCIOUSNESS PROGRAM	13
	<u>SECTION III</u>	
3.	WEIGHT REDUCTION STUDY EFFORT	21
3.1	Summary	21
3.2	Organization	21
3.3	Item 1 - Pressurant Heating	25
3.4	Item 2 - Continuous Venting	25
3.5	Item 3 - Variable Engine Mixture Ratio	27
3.6	Item 4 - Propellant Tank Operating Pressure Reduction	28
3.7	Item 5 - Improved Internal Insulation	28
3.8	Item 6 - Remove Leak Check	29
3.9	Item 7 - Remove Ambient Helium Bottle Insulation	29
3.10	Item 8 - Time Delay Depletion Signal	29

TABLE OF CONTENTS (Cont'd)

Paragraph		Page
3.11	Item 9 - Low Density Electronic Encapsulating Materials	30
3.12	Item 10 - Minimum Weight Attaching Parts	30
3.13	Item 11, 11A - Reduction in Skin Splice Material on Skirts and Interstage	31
3.14	Item 12 - Minimum Weight Core Foam for the LH ₂ Tank Internal Insulation	32
3.15	Item 13 - Solid State Sequencer	32
3.16	Item 14 - "In Place" Welding or Brazing of Tubing	33
3.17	Item 15 - Cryogenic Repressurization	35
3.18	Item 15A - Structural Modifications for Cryogenic Repressurization	35
3.19	Item 16 - Trajectory Optimization	35
3.20	Item 17 - Operational Telemetry	37
3.21	Item 18 - Decreased Chem-Milling Tolerances	37
3.22	Item 19 - Thermo-Conditioning Panel Improvement	37
3.23	Item 20 - Aluminum Tubing and Fittings for the Hydraulic System	38
3.24	Item 21 - Use of Lighter Weight Material in Hydraulic System Accumulator	38
3.25	Item 22 - Material Substitution for Propulsion System Tubing	39
3.26	Item 23 - Wire Weight Reduction	39
3.27	Item 23A - Size Reduction of Copper Wire in E/E Equipment	41
3.28	Item 24 - Welded Module Package Redesign	41
3.29	Item 25 - Electrical Bus Connector Redesign	42
3.30	Item 26 - Use of Color-Coded Hookup Wire	44

TABLE OF CONTENTS (Cont'd)

Paragraph		Page
3.31	Item 27 - Miniaturized Instrumentation System	44
3.32	Item 28 - Electrical Wire Clamps	45
3.33	Item 29 - Reduction of Forward Dome Internal Insulation	45
3.34	Item 30 - Stringer Redesign on Skirts and Interstage	45
3.35	Item 31 - Redesign of Aft Skirt Air Conditioning Duct	46
3.36	Item 32 - Chemical Milling of Skin Sections on Skirts and Interstage	46
3.37	Item 33 - Combination Check Valve and Instrumentation Mount - LH ₂ and LOX Chillydown Return	46
3.38	Item 34 - LH ₂ Non-Propulsive Vent	49
3.39	Item 35 - Zero Gravity Liquid-Gas Separator	49
3.40	Item 36 - Alternate Adhesive for the Common Bulkhead	50
3.41	Item 37 - Redesign of Common Bulkhead	50
3.42	Item 38 - Use of Beryllium-Aluminum Alloy for Skins and Doublers of the Skirts and Interstage	51
3.43	Item 39 - Redesign Electronic Equipment Mounting Panels	51
3.44	Item 40 - Redesign Mounting Bridge, Ullage Rocket Fairing Assembly	51
3.45	Item 41 - S-IVB/V Aft Skirt Skin Thickness Reduction	52
3.46	Item 41A - S-IVB/V Aft Interstage Skin Thickness Reduction	52
3.47	Item 42 - Reverse Flow Engine Chillydown System	52
3.48	Item 43 - Redesign Transducers and Mating Parts from Conoseal to MC Design	55
3.49	Item 44 - Elimination of Cold Helium Bottles on S-IVB/IB	55
3.50	Item 45 - Reduction of Retro-Rocket Shock Factor	55

TABLE OF CONTENTS (Cont'd)

Paragraph		Page
3.51	Item 46 - LH ₂ Cylinder Weight Reduction	56
3.52	Item 47 - Ordnance Thruster Separation System	57
3.53	Item 48 - Passive Thermo-Conditioning System	59
3.54	Item 49 - Relocation of Cold Helium Bottles on S-IVB/IB	60
3.55	Item 50 - Surface Finish Change on S-IVB/V	61
3.56	Item 51 - Air Spring Separation System	61
3.57	Item 52 - Reliability Approach to Structural Design Factors	64

9

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1-1	Douglas Authorized Weight Reduction and Performance Improvement Achievements - S-IVB/V	5
1-2	Douglas Authorized Weight Reduction and Performance Improvement Achievements - S-IVB/IB	7
1-3	MSFC Authorized Weight Reduction and Performance Improvement Achievements - S-IVB/V	9
1-4	MSFC Authorized Weight Reduction and Performance Improvement Achievements - S-IVB/IB	11
3-1	Summary Status of Weight Reduction and Performance Improvement Items	22
3-2	Attaching Parts Weight Data	30
3-3	Skin Splice Reduction Weight Data	31
3-4	Reduced Insulation Density Weight Data	32
3-5	Preliminary Line Break Connection Weight Data	34
3-6	Thermo-Conditioning Panel Weight Data	38
3-7	Accumulator - Reservoir Weight Data	39
3-8	Proposed Propulsion Tubing Changes	40
3-9	Welded Module Packaging Redesign Weight Data	42
3-10	Electrical Bus Connector Redesign Weight Data	43
3-11	Stringer Redesign Weight Data	46
3-12	Common Bulkhead Redesign Weight Data	50
3-13	Lockalloy Skin and Doubler Weight Savings Data	51
3-14	Reverse Flow Engine Chillydown System Weight Saving Data	54
3-15	Thruster Separation System Weight Data	58
3-16	Thermo-Conditioning Forward Skirt Electronics	60

LIST OF TABLES (Cont'd)

<u>Table</u>		<u>Page</u>
3-17	Payload Gains Through Surface Finish Change	62
3-18	Air Spring Separation System Weight Data	64

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1-1	Douglas Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/V	4
1-2	Douglas Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/IB	6
1-3	MSFC Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/V	8
1-4	MSFC Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/IB	10
2-1	S-IVB Weight Control Poster No. 1 - June 1966	14
2-2	Structural/Mechanical Weight Status	15
2-3	Electronics Weight Status	16
2-4	Propulsion Weight Status	17
2-5	S-IVB Weight Control Posters	18
3-1	Repressurization Systems	36
3-2	Proposed Aft Skirt Environmental System	47
3-3	Proposed Redesign Combining Check Valve and Instrumentation Mount	48
3-4	Schematics of Existing and Proposed Engine Chillover Systems	53

SECTION I

INTRODUCTION AND SUMMARY

8

SECTION I

1.0 INTRODUCTION AND SUMMARY

Through the combined efforts of the Douglas Aircraft Company and NASA/MSFC, a two year augmented weight control program was implemented on the Saturn, S-IVB Stage. As a result of design improvements stemming from this program, the operational Saturn IB payload capability was increased by 5,452 pounds, and the operational Saturn V payload capability was increased by 6,299 pounds. In addition, numerous studies were initiated as a result of the augmented weight control program providing the means for even greater payload improvements, which are available in the event that follow-on Saturn programs require improved payload capability.

It is the purpose of this report to summarize the achievements of the augmented weight control program, and to briefly describe, for future reference, potential payload improvement ideas which have not been implemented.

1.1 The Teamwork Approach

As a result of unfavorable weight growth problems on the Saturn Program, in mid 1964 Douglas was directed to study means to improve vehicle payload capability, and to propose to NASA those improvements which were consistent with overall program objectives. This effort was to continue until mid 1966.

Wherever possible, within the constraints of funding, schedules, and specification requirements, Douglas implemented design changes for payload improvement within the scope of the basic contract. These improvements, highlighted in Section 1.2, resulted in payload gains of 938 pounds on the operational Saturn IB and 932 pounds on the operational Saturn V.

Where design changes for payload improvement were clearly outside the boundaries of funding, schedules and technical constraints on Douglas, NASA/MSFC directed such changes through appropriate modifications to the contract. These changes,

highlighted in Section 1.3, resulted in payload gains of 4,514 pounds on the operational Saturn IB and 5,367 pounds on the operational Saturn V.

It was this unique combination of government industry teamwork that resulted in aggregate payload gains of two and one-half tons of payload on the Saturn IB and three tons of payload on the Saturn V through improvements in the S-IVB Stage.

1.2 Highlights of DAC Implemented Changes

DAC implemented design improvement changes on the S-IVB resulted in payload gains of 938 pounds and 932 pounds on the operational Saturn IB and Saturn V, respectively. Outstanding among these changes are improved internal insulation (517 pounds on both IB and V), removal of leak check (190 pounds on V, 165 pounds on IB), removal of insulation on ambient helium bottles (158 pounds on V) and elimination of two cold helium bottles (205 pounds on IB). Tables 1-1 and 1-2 and Figures 1-1 and 1-2 provide a listing and graphic presentation of these and other applicable DAC implemented design improvement changes. In addition, brief technical descriptions of each change may be found in Section III.

1.3 Highlights of MSFC Directed Changes

MSFC directed design changes on the S-IVB resulted in payload gains of 5,367 pounds and 4,514 pounds on the operational Saturn V and Saturn IB, respectively. Outstanding among these changes are operational telemetry (1,835 pounds on V, 1,686 pounds on IB), continuous venting (1,888 pounds on V) variable EMR (2,010 pounds on IB), cryogenic repressurization (925 pounds on V), and time delay of depletion sensors (530 pounds on both IB and V). Tables 1-3 and 1-4 and Figures 1-3 and 1-4 provide a listing and graphic presentation of these and other applicable MSFC directed changes. In addition, a brief description of each change may be found in Section III. Note that the estimate of payload gain resulting from variable EMR (Table 1-4) has been revised from previously published values as a result of more refined analysis.

1.4 Weight Consciousness Program

When the augmented weight control program was initiated, it was recognized that effective weight control is achieved through the efforts of many people, and that payload gains achieved through difficult and costly redesigns

could be lost if everyone connected with the design and program management of the Saturn program was not made aware of the importance of weight control. As a result, a weight consciousness program was initiated, utilizing colorful and attention-getting posters and charts, with the two-fold objective of (1) highlighting the importance of weight control, thus encouraging designers to "think light" and avoid unnecessary weight growth, and (2) to encourage and stimulate ideas which could be incorporated in the weight reduction study effort.

Examples of materials used in the weight consciousness program are contained in Section II of this report.

1.5 Weight Reduction Study Effort

A continuous two year weight reduction and performance improvement study effort was initiated in July 1964 conducted by design specialists in the applicable engineering areas. In addition, a Monthly Weight Control Status Report was initiated to reflect the results of this study effort. This being the final report in the series of reports designed to document the results of the study efforts, a brief description has been provided in Section III of all studies previously reported, including implemented design improvements.

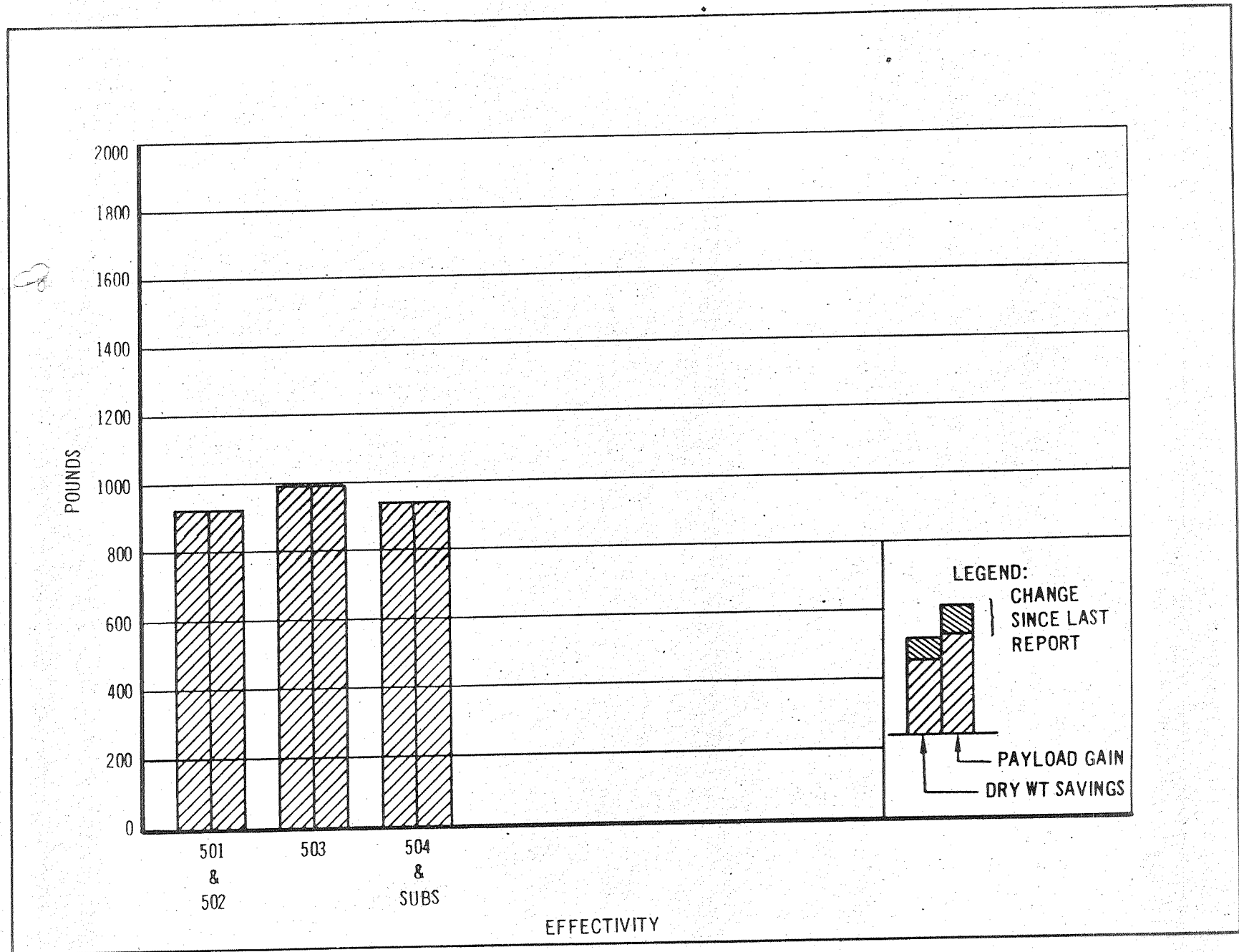


Figure 1-1. Douglas Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/V

TABLE 1-1

DAC AUTHORIZED WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ACHIEVEMENTS

S-IVB/V

Item	Description	Authority	Date	501 & 502		503		504 & Subs		DWS	PG	DWS	PG
				DWS	PG	DWS	PG	DWS	PG				
5	Improved Internal Insulation	Internal Paper	8-1-64	517	517	517	517	517	517				
6	Remove Leak Check *A3-860-K010-4.20.6-L-41	Letter*	8-1-64	190	190	190	190	190	190				
7	Remove Ambient Helium Bottle Insulation	Internal Paper	9-10-64	158	158	158	158	158	158				
35	Zero Gravity Liquid-Gas Separator	Internal Paper	1-22-65	17	17	17	17	17	17				
25	Bus Connector Redesign	WRO-575	6-4-65	---	---	13	13	13	13				
9	Low Density Electronic Encapsulating Materials	WRO-840	7-23-65	---	---	35	35	10	10				
11A	Reduction in Skin Splice Material on S-IVB/V Aft Skirt	DAC DWG LA39295	1-16-65	6	6	6	6	6	6				
28	Electrical Wire Clamps	WRO-786	7-10-65	---	---	21	21	13	13				
39	Redesign Electronic Equip- ment Mounting Panels	DAC Dwgs.	Sept. 1965	32	32	32	32	8	8				
	TOTAL (Last Report)			920	920	989	989	932	932				
	No change this report												

DWS = Dry Weight Savings (lb.)

PG = Payload Gain (lb.)

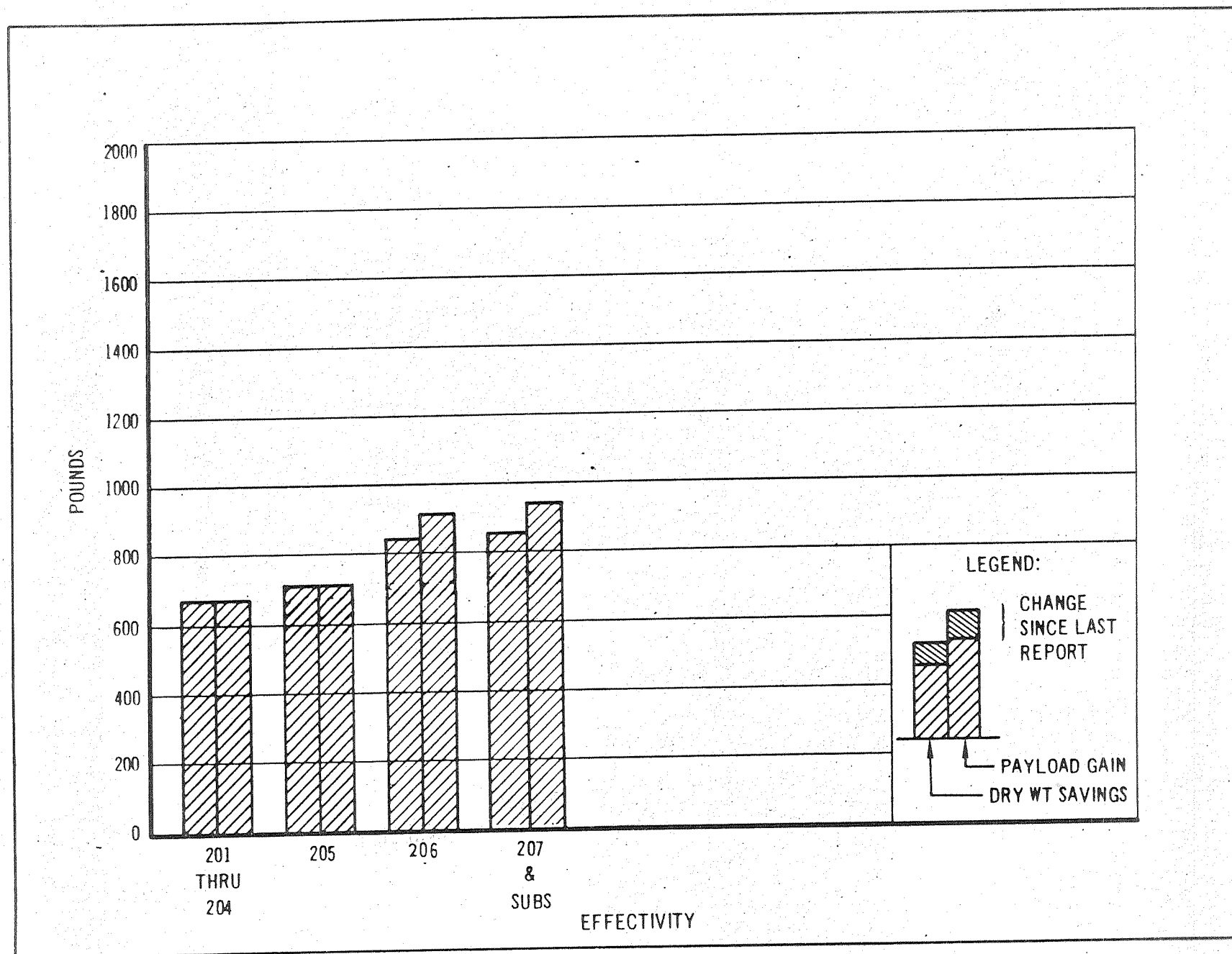


Figure 1-2. Douglas Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/IB

TABLE 1-2

DAC AUTHORIZED WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ACHIEVEMENTS

S-IVB/IB

Item	Description	Authority	Date	201 → 204		205		206		207 & Subs		DWS	PG
				DWS	PG	DWS	PG	DWS	PG	DWS	PG		
5	Improved Internal Insulation	Internal Paper	8-1-64	517	517	517	517	517	517	517	517		
6	Remove Leak Check *A3-860-K010-4.20.6-L-41	Letter*	8-1-64	165	165	165	165	165	165	165	165		
25	Bus Connector Redesign	WRO-575	6-4-65	---	---	---	---	---	---	13	13		
9	Low Density Electronic Encapsulating Materials	WRO-840	7-23-65	---	---	---	---	---	---	9	9		
28	Electrical Wire Clamps	WRO-786	7-10-65	---	---	11	11	11	11	11	11		
39	Redesign Electronic Equipment Mounting Panels	DAC Dws.	Sept. 1965	---	---	18	18	18	18	18	18		
44	Elimination of Cold Helium Bottles on S-IVB/IB	WRO-086A	11-24-65					123	205	123	205		
	TOTAL (Last Report)			682	682	711	711	834	916	856	938		
	No change this report												

DWS = Dry Weight Savings (lb.)
PG = Payload Gain (lb.)

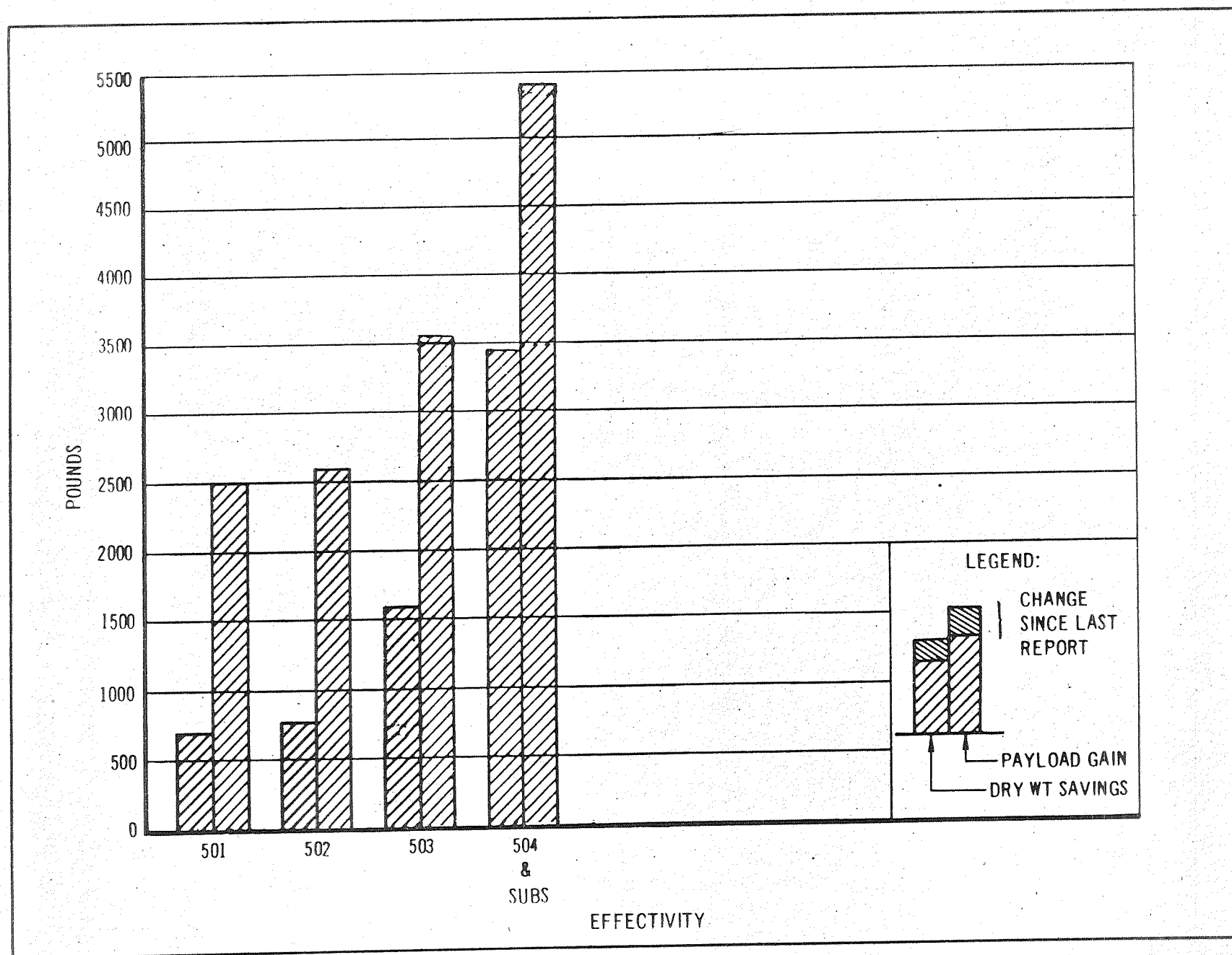


Figure 1-3. MSFC Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/V

TABLE 1-3

MSFC AUTHORIZED WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ACHIEVEMENTS

S-IVB/V

Item	Description	Authority	Date	501		502		503		504 & Subs		DWS	PG
				DWS	PG	DWS	PG	DWS	PG	DWS	PG		
2	Continuous Venting	S/C 1221	5-26-64	526	1888	526	1888	526	1888	526	1888		
4	Propellant Tank Operating Pressure Reduction	S/C 1304	5-29-64	175	125	175	125	175	125	175	125		
8	Time Delay Depletion Signal	S/C 1376A	10-1-64	0	530	0	530	0	530	0	530		
18	Decreased Chem-Milling Tolerances	S/C 1312	11-1-64	---	---	89	89	89	89	89	89		
17	Operational Telemetry (with out FM/FM "Add-On" Kit)	ECP X132	6-3-65	---	---	---	---	---	---	1865	1835		
15A	Structural Modifications for Cryogenic Repressurization	ECP X126	9-21-65	---	---	---	---	-25	-25	-25	-25		
15	Cryogenic Repressurization	ECP X181	12-15-65	---	---	---	---	821	932	814	925		
	TOTAL (Last Report)			701	2543	790	2632	1586	3539	3444	5367		
	No change this report												

DWS = Dry Weight Savings (lb.)

PG = Payload Gain (lb.)

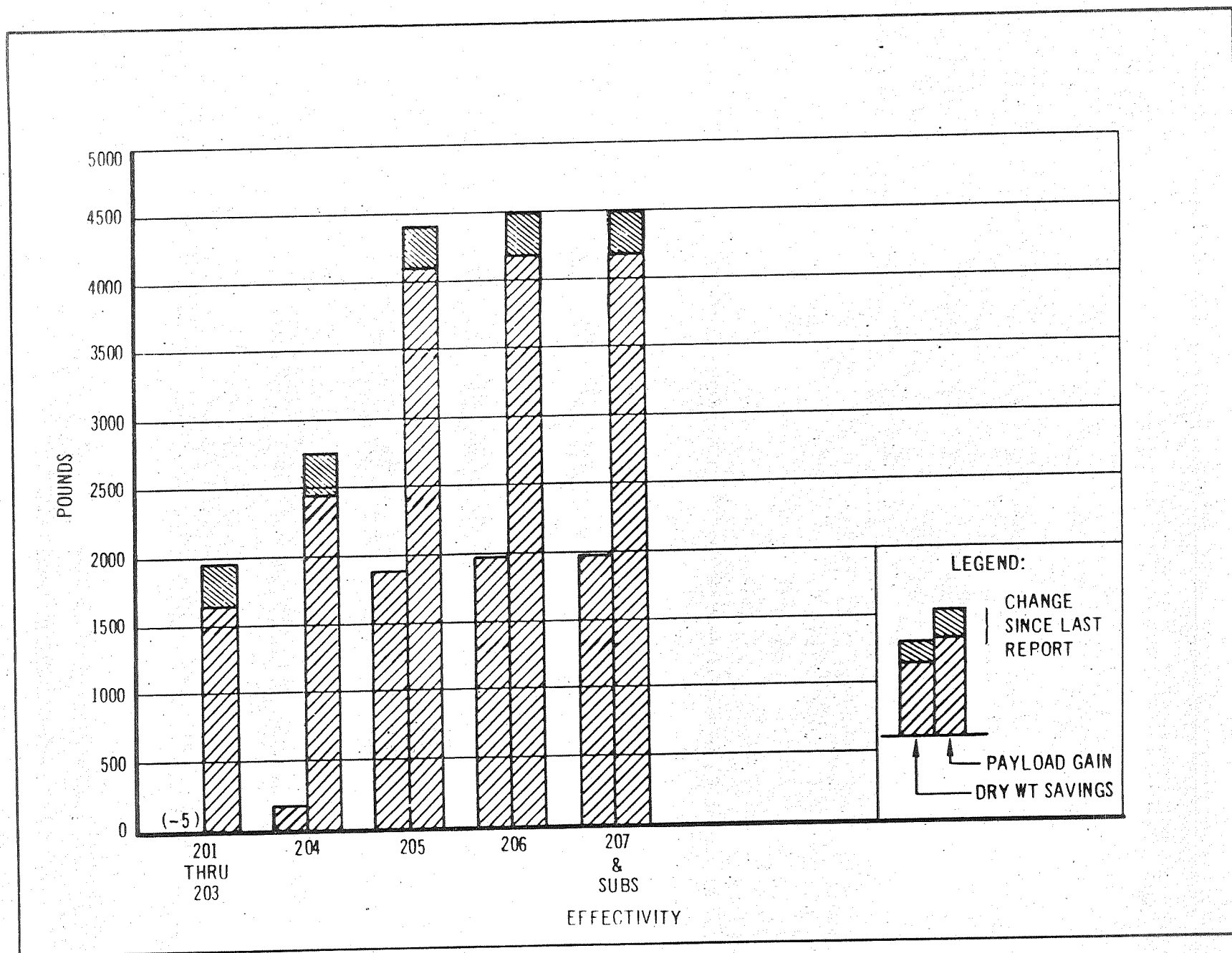


Figure 1-4. MSFC Authorized Weight Reduction and Performance Improvement Achievements, S-IVB/IB

TABLE 1-4

MSFC AUTHORIZED WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ACHIEVEMENTS

S-IVB/IB
2

Item	Description	Authority	Date	201 - 203		204		205		206		207 & Subs	
				DWS	PG	DWS	PG	DWS	PG	DWS	PG	DWS	PG
3	Variable EMR	S/C 1207	6-2-64	-5	1700	-5	1700	-5	1700	-5	1700	-5	1700
4	Propellant Tank Operating Pressure Reduction	S/C 1304	6-29-64	---	---	175	200	175	200	175	200	175	200
8	Time Delay Depletion Signal	S/C 1376A	10-1-64	---	---	0	530	0	530	0	530	0	530
18	Decreased Chem-Milling	S/C 1312	11-1-64	---	---	---	---	---	---	89	89	89	89
17	Operational Telemetry (with out FM/FM "Add-On" Kit)	ECP X132	6-3-65	---	---	---	---	1724	1686	1724	1686	1724	1686
15A	Structural Modifications for Cryogenic Repressurization	ECP X126	6-16-65	---	---	---	---	---	---	---	---	-1	-1
TOTAL (Last Report)				-5	1700	170	2430	1894	4116	1983	4205	1982	4204
3'	Variable EMR				310		310		310		310		310
TOTAL (This Report)				-5	2010	170	2740	1894	4426	1983	4515	1982	4514

DWS = Dry Weight Savings (lb.)
PG = Payload Gain (lb.)

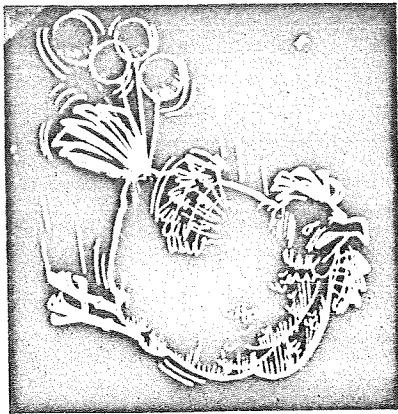
SECTION II

WEIGHT CONSCIOUSNESS PROGRAM

SECTION II

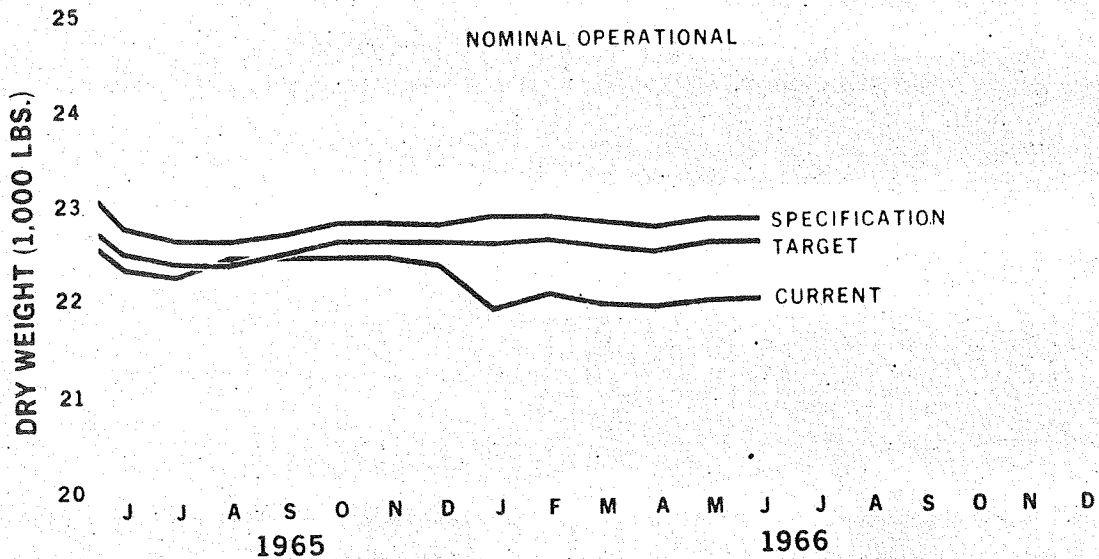
2. WEIGHT CONSCIOUSNESS PROGRAM

The "weight consciousness" program was initiated in September of 1964 to emphasize, by various types of communication media, the importance of weight control at all levels of Engineering and Management. Design goals, Figures 2-1 thru 2-4, have been prominently displayed in the Design Departments. In addition, multicolor weight consciousness posters, such as shown in Figure 2-5 are displayed throughout the area. The design goals are updated and revised as necessary each month. New posters also are displayed monthly.



VIP

S-IVB/ IB DESIGN WEIGHT STATUS - DRY STAGE



S-IVB/V DESIGN WEIGHT STATUS - DRY STAGE

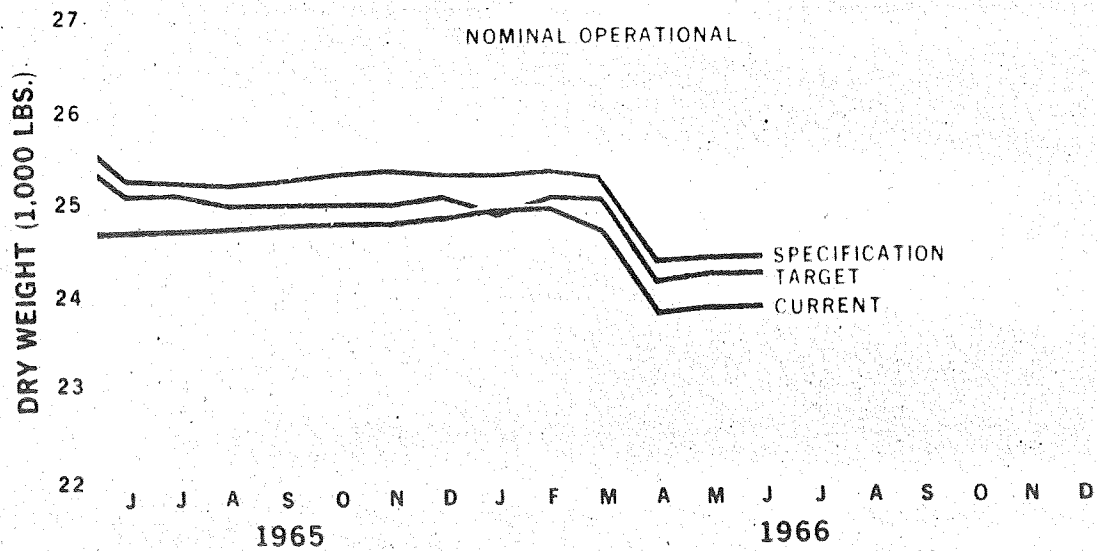


Figure 2-1.

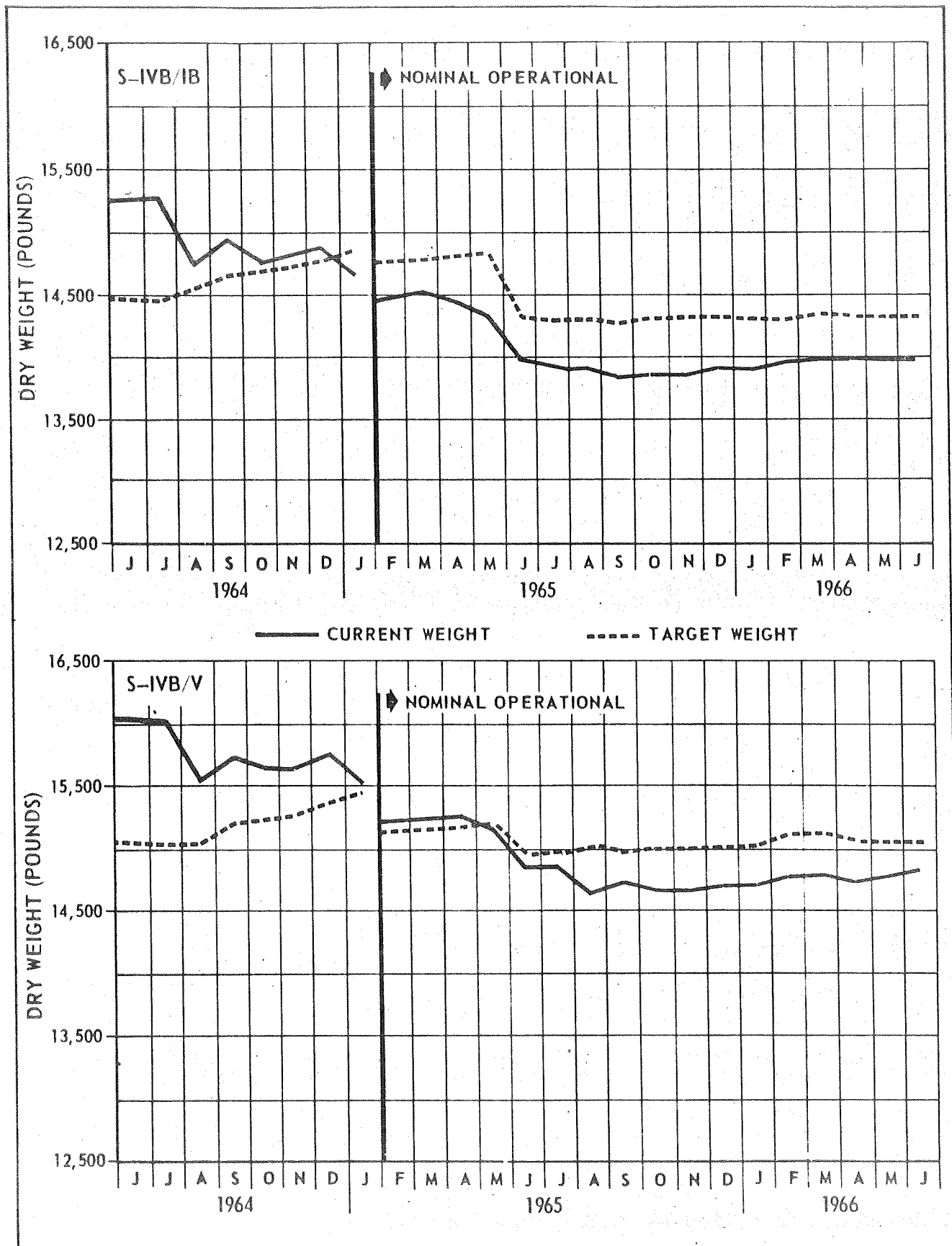


Figure 2-2. Structural/Mechanical Weight Status

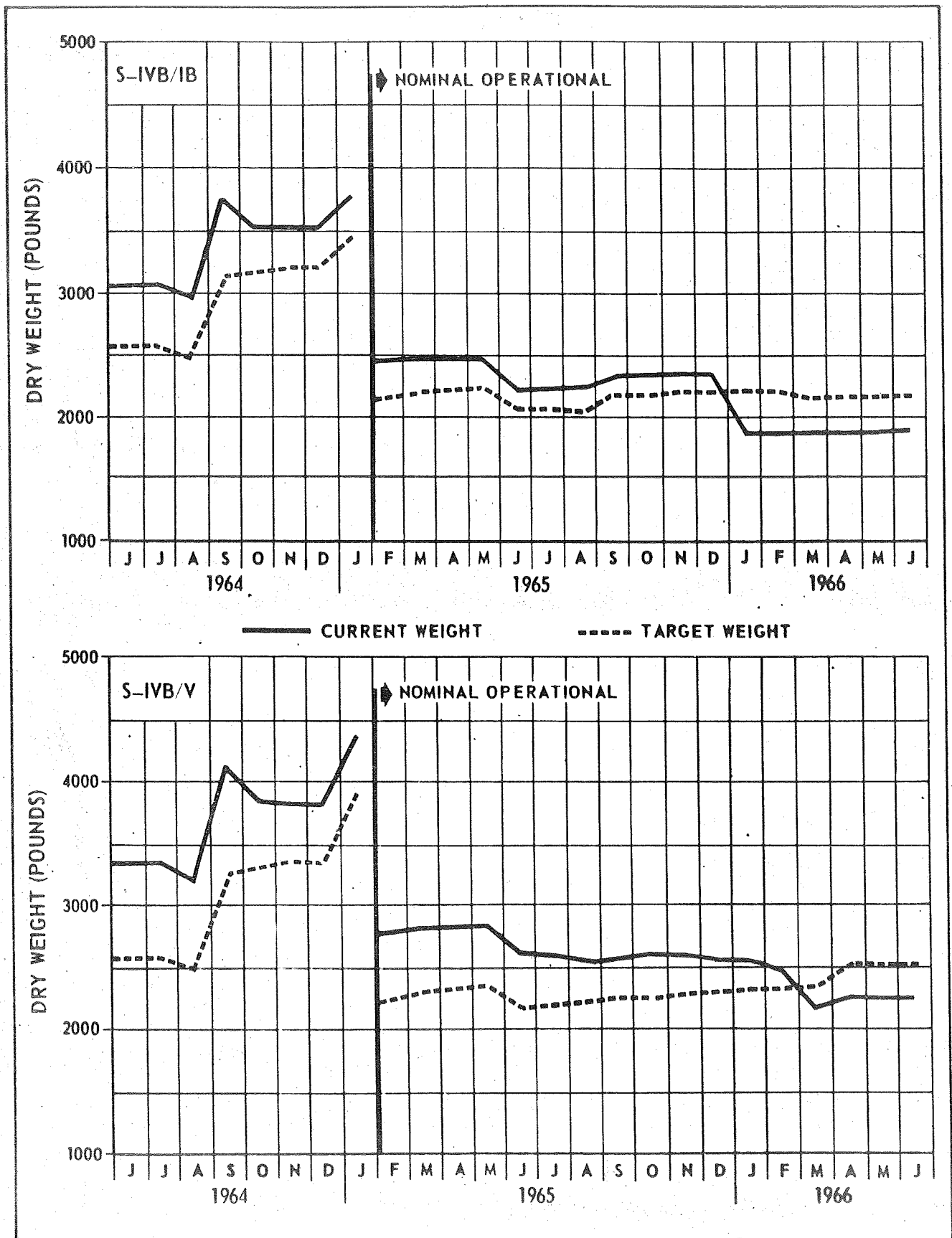


Figure 2-3. Electronics Weight Status

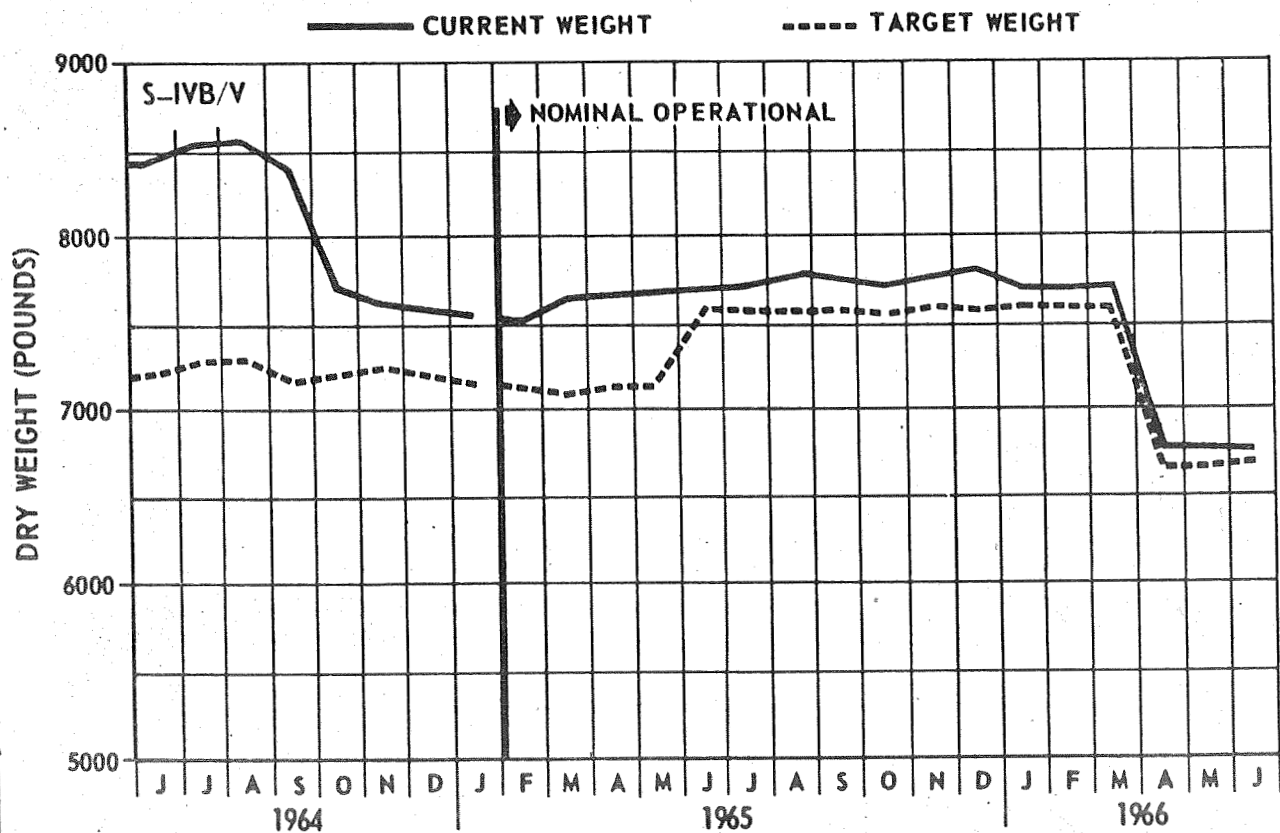
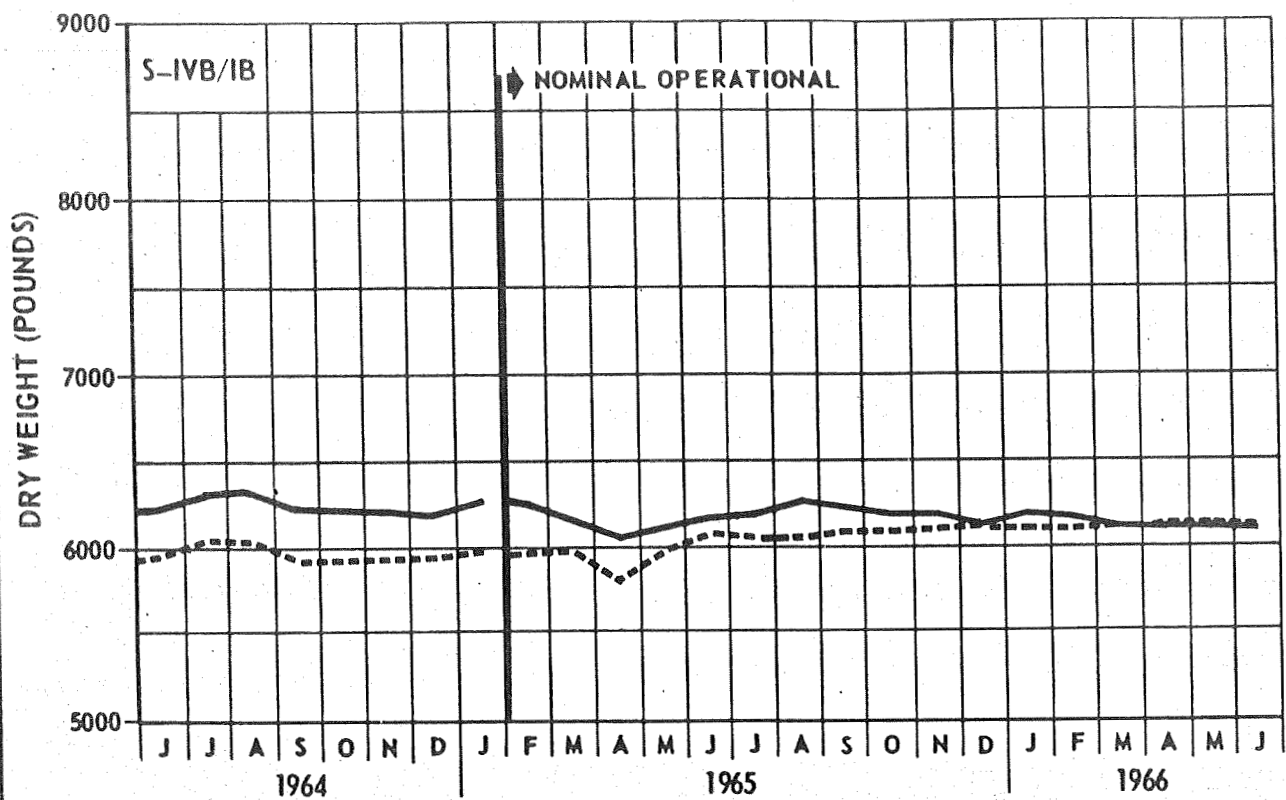
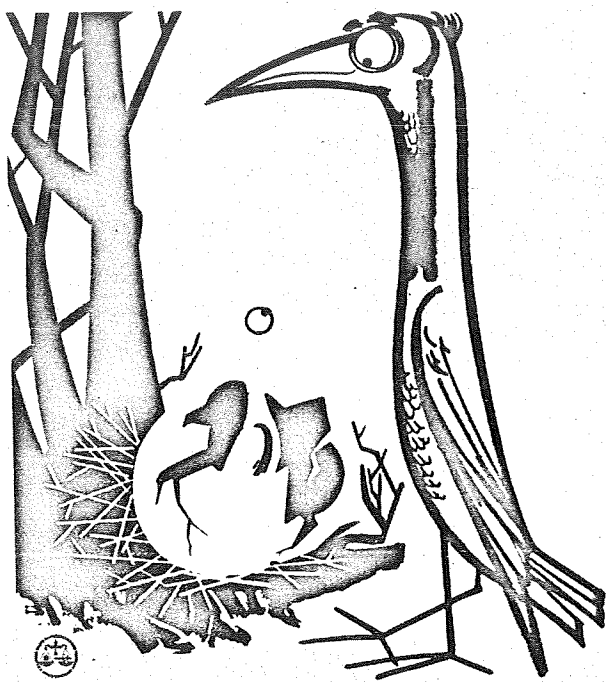
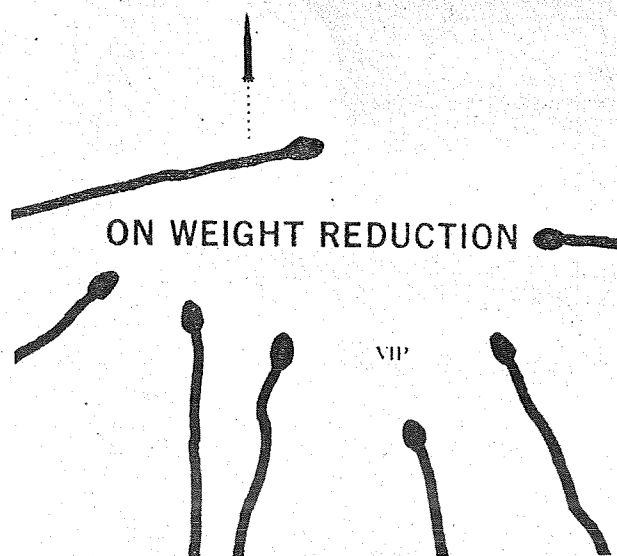


Figure 2-4. Propulsion Weight Status



WEIGHT



OVERSTUFFING will make it a turkey

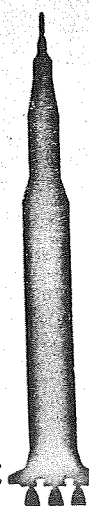


FIGURE 2.5

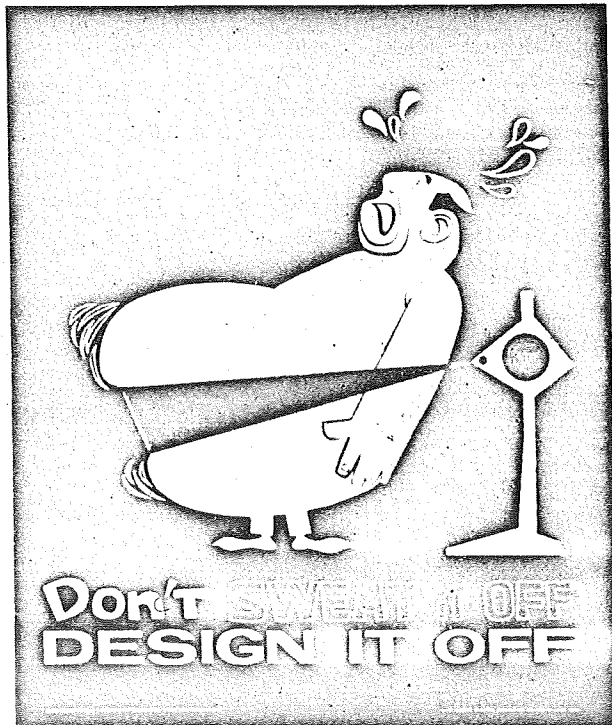
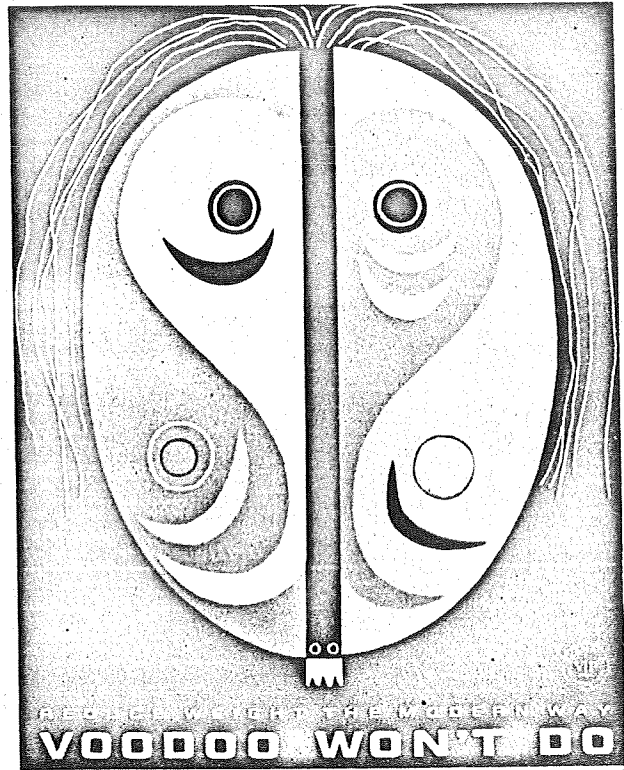
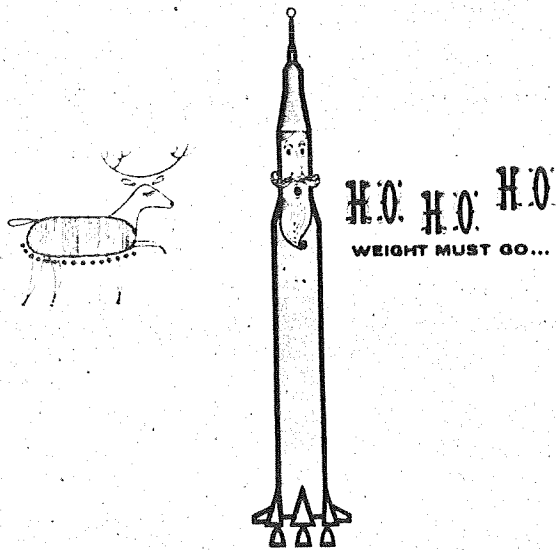


FIGURE 2.5A

SECTION III

WEIGHT REDUCTION STUDY EFFORT

SECTION III

3. WEIGHT REDUCTION STUDY EFFORT

3.1 Summary

The Douglas weight reduction and performance study effort was initiated to investigate "means" to reduce the S-IVB Stage weight and/or improve its flight performance. These means to reduce weight and/or improve performance were introduced as study items and studied until implemented into the design or discontinued.

3.2 Organization

Table 3-1 summarizes the final status of each weight reduction and performance improvement item, including a notation as to whether each item has been implemented, discontinued, or is still under study.

Following Table 3-1 are a series of brief descriptions of each study item. Since this is the last report of this type, descriptions are given of all items regardless of whether they have been discontinued, implemented, or are still active.

In addition, an index of all previous reports has been included at the end of this section to facilitate reference to prior reports which may contain more complete data on each study item.

TABLE 3-1

SUMMARY STATUS OF WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ITEMS

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>STATUS</u>	<u>SEQUENCE* OF CONCLUDING REPORT</u>
1	Pressurant Heating	Discontinued	7
2	Continuous Venting	Implemented	0
3	Variable EMR	Implemented	0
4	Propellant Tank Operating Pressure Reduction	Implemented	0
5	Improved Internal Insulation	Implemented	0
6	Remove Leak Check	Implemented	0
7	Remove Ambient Helium Bottle Insulation	Implemented	0
8	Time Delay Depletion Signal	Implemented	0
9	Low Density Electronic Encapsulating Materials	Implemented	10
10	Minimum Weight Attaching Parts	Discontinued	16
11	Reduction in Skin Splice Material on Skirts and Interstage	Discontinued	12
11A	Reduction in Skin Splice Material on S-IVB/V Aft Skirt	Implemented	10
12	Minimum Weight Core Foam for the LH ₂ Tank Internal Insulation	Discontinued	14
13	Solid State Sequencer	Discontinued	11
14	"In Place" Welding or Brazing of Tubing	Discontinued	10
15	Cryogenic Repressurization	Implemented	12
15A	Structural Modifications for Cryogenic Repressurization	Implemented	10
16	Trajectory Optimization	Discontinued	5
17	Operational Telemetry	Implemented	7 & 10
13	Decreased Chem-Milling Tolerances	Implemented	1

TABLE 3-1 (Cont'd)

SUMMARY STATUS OF WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ITEMS

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>STATUS</u>	<u>SEQUENCE* OF CONCLUDING REPORT</u>
19	Thermo-Conditioning Panel Improvements	Discontinued	11
20	Aluminum Tubing and Fittings for the Hydraulic System	Discontinued	5
21	Use of Lighter Weight Material in Hydraulic System Accumulator	Discontinued	10
22	Material Substitution for Propulsion System Tubing	Discontinued	12
23	Wire Weight Reduction	Discontinued	12
23A	Size Reduction of Copper Wire in E/E Equipment	Discontinued	11
24	Welded Module Packaging Redesign	Discontinued	13
25	Electrical Bus Connector Redesign	Implemented	5
26	Use of Color-Coded Hookup Wire	Discontinued	7
27	Miniaturized Instrumentation System	Discontinued	9
28	Electrical Wire Clamps	Implemented	10
29	Reduction of Forward Dome Internal Insulation	Discontinued	18
30	Stringer Redesign on Skirts and Interstage	Under Study	
31	Redesign of Aft Skirt Air Conditioning Duct	Discontinued	13
32	Chemical Milling of Skin Sections on Skirts and Interstage	Discontinued	10
33	Combination Check Valve and Instrumentation Mount - LH ₂ and LO ₂ Chillover Return	Discontinued	13
34	LH ₂ Non-Propulsive Vent	Under Study	
35	Zero Gravity Liquid-Gas Separator	Implemented	5
36	Alternate Adhesive for the Common Bulkhead	Discontinued	11

TABLE 3-1 (Cont'd)

SUMMARY STATUS OF WEIGHT REDUCTION AND PERFORMANCE IMPROVEMENT ITEMS

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>STATUS</u>	<u>SEQUENCE* OF CONCLUDING REPORT</u>
37	Redesign Common Bulkhead	Discontinued	18
38	Use of Beryllium-Aluminum Alloy for Skins and Doublers of the Skirts and Interstage	Discontinued	18
39	Redesign Electronic Equipment Mounting Panels	Implemented	12
40	Redesign Mounting Bridge, Ullage Rocket Fairing Assembly	Discontinued	13
41	S-IVB/V Aft Skirt Skin Thickness Reduction	Under Study	
41A	S-IVB/V Aft Interstage Skin Thickness Reduction	Discontinued	11
42	Reverse Flow Engine Chillydown System	Discontinued	11
43	Redesign Transducers and Mating Parts from Conoseal to MC Design	Discontinued	13
44	Elimination of Cold Helium Bottles on S-IVB/IB	Implemented	14
45	Reduction of Retro-Rocket Shock Factor	Discontinued**	
46	LH ₂ Cylinder Weight Reduction	Discontinued**	
47	Ordnance Thruster Separation System	Discontinued**	
48	Passive Thermo-Conditioning System	Discontinued	17
49	Relocation of Cold Helium Bottles on S-IVB/IB	Discontinued	18
50	Surface Finish Change on S-IVB/V	Discontinued**	
51	Air Spring Separation System	Discontinued**	
52	Reliability Approach to Structural Design Factors	Under Study	

*See Index (0 = Action prior to first report)

**This Report

3.3 Item 1 - Pressurant Heating

This item proposes to improve payload capability by increasing the efficiency of the fuel tank pressurization system which consists of tapping off GH_2 from the J-2 Engine and feeding it to the fuel tank ullage space during powered flight.

This is accomplished by using the J-2 Engine heat exchanger for additional fuel tank pressurant (GH_2) heating. Hardware changes would include connecting the J-2 Engine heat exchanger in series with the fuel tank pressurization control module, providing a by-pass line with an orifice in parallel with the heat exchanger and control module, and providing inlet and outlet connections on the Rocketdyne Customer Connect Panel.

The amount of fuel tank pressurant (GH_2) required is reduced due to the increased temperature of GH_2 , which decreases its density, thereby reducing residual gas weight by approximately 154 pounds for S-IVB/IB and 135 pounds for the S-IVB/V. The associated hardware changes would amount to an estimated dry stage weight increase of 30 pounds.

3.4 Item 2 - Continuous Venting

This item consists of changing the vent system from a cyclic venting to a continuous venting system. These systems provide for propellant settling and orbital venting of the propellant tanks. In order to help understand the change from cyclic to continuous venting systems, a brief description of each system follows:

Cyclic Venting System

The cyclic venting system is based on venting of the propellant tanks only upon demand. During most of the orbital coast period, the tank vent valves are closed and no attempt is made to control propellant orientation. When the fuel tank pressure rises to a certain level, a vent cycle is initiated by a pressure switch. The propellants are first settled at the aft ends of the tanks by means of ullage rockets. The vent valve is then opened

pneumatically for a fixed amount of time and the tanks are blown down through propulsive nozzles, which permit shutdown of the ullage engines. Just prior to restart, the propellants are again settled, using the ullage rockets, and the propellant tanks are blown down and repressurized with helium in order to meet engine Net Positive Suction Head (NPSH) requirements.

Continuous Venting System

The continuous venting system is based on venting of the propellant tanks continually during the orbital coast period. At first burn main engine cutoff, two axially directed 70 pound thrust engines located in the APS modules burn for 50 seconds to insure that the propellants are settled before the continuous venting is initiated. Once initiated, continuous venting operates until engine restart. The thrust from the continuous vent system is directed axially to provide approximately 2×10^{-5} g forward acceleration to keep the propellants settled. This system will assure that the propellants will be settled for engine restart and will result in a reduction in propellant boiloff. The reduction in boiloff is due to having the propellants settled and not "free floating" in the tanks, which would allow a greater heat input through the tank sidewalls.

The change from a cyclic venting to a continuous venting system would be accomplished by the following hardware changes:

- 1) Eliminate two 1,750 pound thrust ullage engines for S-II/S-IVB separation and engine start.
- 2) Eliminate two 150 pound thrust ullage engines for cyclic venting and engine restart.
- 3) Utilize the Gemini Orbital Attitude and Maneuver System engine (derated to nominally 70 pounds thrust at S-IVB system operated pressure) and propellant valve arrangement for initial orbital ullage control and propellant settling for engine restart.

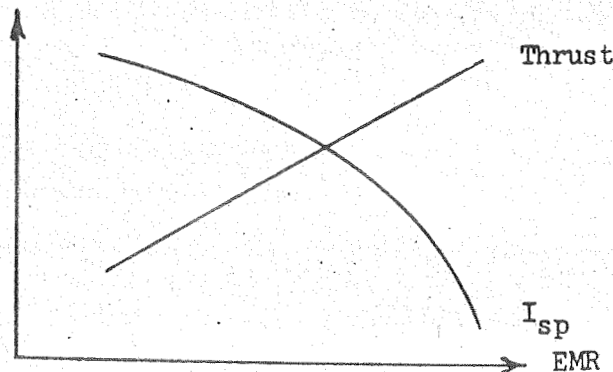
- 4) Optimize the APS propellant tank capacity to meet the present mission requirements including a total ullage time of 454 seconds.
- 5) Design a cold gaseous hydrogen venting system capable of providing a minimum continuous vehicle net forward axial thrust of five (5) pounds during the 4-1/2 hour orbital coast period.
- 6) Utilize two (2) Thiokol TX-280 solid ullage motors and associated hardware per stage for S-II/S-IVB separation and engine start.
Also, design a jettisonable system for the motors and fairings.

3.5 Item 3 - Variable Engine Mixture Ratio

This item achieves substantial S-IVB/IB Stage performance gains by deviating from the general method of operating a stage rocket engine at a fixed thrust - specific impulse (I_{sp}) level throughout flight. The relationships between engine thrust, I_{sp} , and engine mixture ratio (EMR), while allowing in-flight variation of EMR (the independent variable), show that the most efficient EMR history reflects high values of thrust at stage ignition and changes continuously to lower values up to engine cutoff.

The advantage of high thrust early in flight is accounted for by considering a general trajectory shape in which large flight path angles are sensitive to thrust, due to gravity effects, and low flight path angles are relatively insensitive to thrust.

The J-2 Engine has an I_{sp} history that decreases with increasing thrust and is schematically illustrated in the following figure.



This engine characteristic is utilized through the use of the Propellant Utilization (PU) System which is designed to recognize errors in the ratio of loaded LOX to loaded LH₂, and to correct such errors by forcing the engine to operate in the direction of the error. This means that mass ratios of LOX to LH₂, which are different from a predesignated value of EMR that is programmed into the PU system, can be deliberately loaded causing the engine to operate at EMR's in the desired direction.

Therefore, by deliberately loading LOX-rich, the engine operation during the early portion of flight will be at a high EMR (high thrust) until the error is removed by the PU system. At this time, the engine will revert back to the EMR (low thrust) that is initially programmed into the PU system for the remaining portion of flight.

The performance gain of 2,010 pounds shown in Section I, Introduction and Summary, is based on an EMR value of 4.7, which is initially programmed into the PU system, and a loaded LOX to LH₂ mass ratio of 5.3.

3.6 Item 4 - Propellant Tank Operating Pressure Reduction

This weight reduction item is a result of reduced J-2 Engine NPSH requirements. The S-IVB hydrogen tank ullage limit pressure can be lowered from 42 psia to 39 psia for the S-IVB/IB Stages, and from 42 psia to 37 psia for the S-IVB/V Stages. As a result of the reduced ullage limit pressure, the LH₂ forward dome and cylindrical sidewall can be redesigned for lower hoop tension design loads, which result in a significant dry stage weight savings. Also, associated with this change is a reduction of residual gasses and an increase to LH₂ boiloff, during orbital coast, for the S-IVB/V Stage.

3.7 Item 5 - Improved Internal Insulation

This item proposes to reduce internal insulation weight by using an improved manufacturing method. This method consists of using a vacuum bag technique in applying the insulation liner to the insulation core. By using this technique, a three-fold weight improvement is realized by:

- 1) A reduction of resin in the liner, due to the uniform pressure applied during the cure cycle.
- 2) A reduction of liner cloth weight was found possible during the testing to verify the vacuum bag technique.
- 3) Elimination of some of the doublers used at the liner joints due to using lighter weight liner cloth.

3.8 Item 6 - Remove Leak Check

This weight reduction item is achieved by the removal of the design requirements for a leak detection system on the S-IVB/IB and S-IVB/V Stages. By removal of this requirement, all doubler seal joints and pressure transducers, which are employed at all points in the stage carrying pneumatic pressures or cryogenic fluids in an active sense during flight, can be deleted.

3.9 Item 7 - Remove Ambient Helium Bottle Insulation

This weight reduction item consist of removing the insulation shrouds from seven fuel repressurization helium bottles (ambient) and two LOX repressurization helium bottles (ambient) located on the thrust structure. This is accomplished due to the results of a thermal analysis which shows that a bare uncoated titanium bottle will result in approximately the same helium temperatures at the end of a 4-1/2 hour orbit period as a bottle surrounded by a fiberglass shell.

3.10 Item 8 - Time Delay Depletion Signal

This item increases payload capability by utilizing the propellants that are trapped in the tanks below the depletion sensors, and is accomplished through the use of a time delay circuit which permits the engine to operate for a predetermined time after the propellants reach the depletion sensors. Therefore, the residual propellant levels are lowered from approximately the height of the sensors down to the center line of the LH₂ feed duct for LH₂ and to the geometrical bottom of the tank for LOX, which accounts for a significant reduction in residual propellant weight.

3.11 Item 9 - Low Density Electronic Encapsulating Materials

This weight reduction item is accomplished by replacing epoxy material (density of 0.054 lbs/in³) used for encapsulating electronic modules with a filled material (i.e., resinous compound mixed with organic or inorganic material) that has an approximate density of 0.029 lbs/in³.

3.12 Item 10 - Minimum Weight Attaching Parts

This proposed weight reduction item consists of replacing the existing steel bolts (NAS 1466 and NAS 1476) with equivalent titanium bolts (NAS 2006 and NAS 2106) on the following drawings:

<u>S-IVB/IB</u>		<u>S-IVB/V</u>	
1B29835	Forward Skirt	1A39264	Forward Skirt
1B29825	Aft Skirt	1A39295	Aft Skirt
1A39316	Thrust Structure	1A39316	Thrust Structure
1B28836	Aft Interstage	1A70707	Aft Interstage

Table 3-2 presents the expected dry weight savings and payload gains.

TABLE 3-2

ATTACHING PARTS WEIGHT DATA

		Present Weight	Titanium Weight	Dry Weight Savings	Payload Gain
Saturn S-IVB/IB	Stage	55.8	31.2	24.6	24.6
	Interstage	23.6	13.2	10.4	1.3
	TOTAL	79.4	44.4	35.0	25.9
Saturn S-IVB/V	Stage	55.1	30.8	24.3	24.3
	Interstage	14.7	8.2	6.5	2.2
	TOTAL	69.8	39.0	30.8	26.5

3.13 Item 11, 11A - Reduction in Skin Splice Material on Skirts and Interstage

The forward skirt, aft skirt, and interstage are each built up by splicing panel assemblies together. The splice consists of riveting overlapped panel skins to stringers, as shown in the sketch below. This item proposes to reduce the skin overlap at each splice as shown by the cross-hatched area in the sketch.

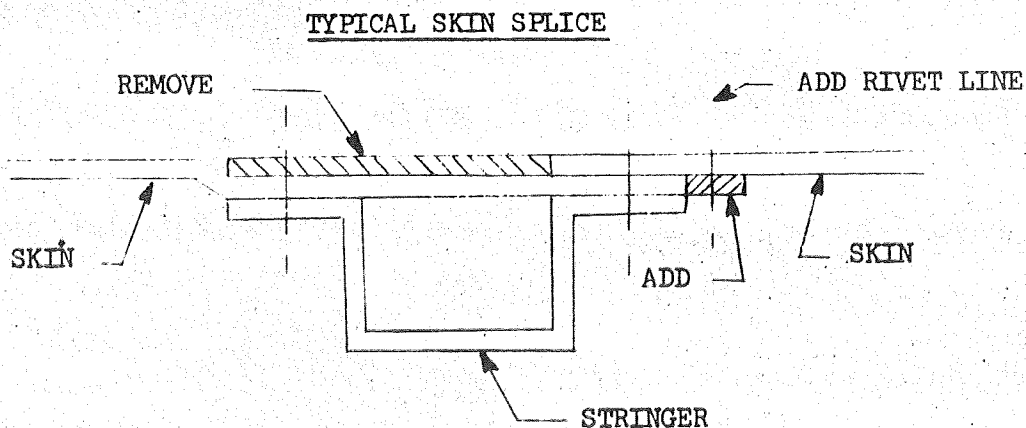


Table 3-3 presents the weight data for this item.

TABLE 3-3

SKIN SPLICE REDUCTION WEIGHT DATA

	<u>Dry Weight Savings</u>	<u>Payload Gain</u>
<u>S-IVB/IB</u>		
Forward Skirt	6.4	6.4
Aft Skirt	4.6	4.6
Aft Interstage	10.0	1.2
Total	21.0	12.2
 <u>S-IVB/V</u>		
Forward Skirt	6.4	6.4
Aft Skirt (Implemented as Item 11A)	(5.6)	(5.6)
Aft Interstage	20.0	6.7
Total	26.4	13.1

3.14 Item 12 - Minimum Weight Core Foam for the LH₂ Tank Internal Insulation

This item proposes to replace the existing polyurethane core material for the LH₂ internal insulation with a less dense polyurethane material.

Table 3-4 presents the weight savings associated with various densities of core materials.

TABLE 3-4

REDUCED INSULATION DENSITY WEIGHT DATA

<u>Core Density</u> <u>(lb/ft³)</u>	<u>Core</u> <u>Weight</u> <u>(lb)</u>	<u>Weight Saving Over</u> <u>Present Configuration</u> <u>(lb)</u>
5.5 (present. config.)	821	---
5.0	747	74
4.5	672	149
4.0	597	224
3.5	523	298
3.0	448	373

3.15 Item 13 - Solid State Sequencer

The existing sequencer is replaced by a solid stage sequencer. The electro-mechanical relays now used would be replaced with solid state transistorized switches. This miniaturization would result in a large reduction in the size and weight of the container needed in addition to the weight saving for each relay or switch.

Increased reliability and faster switching response would also be realized due to the elimination of the mechanical moving parts.

The solid state sequencer would be developed to replace the present sequencer on the S-IVB Stage without change to the vehicle wiring or mounting structure. The weight saving involved would be approximately 15 pounds.

3.16 Item 14 - "In Place" Welding or Brazing of Tubing

This item suggests that "in place" welding or brazing of tubes be used in lieu of the conventional coupling connections. The sketches below, except for Figure II, show that both the welding and brazing technique involves encasing the tube ends in a light-weight sleeve. In one case, the sleeve is welded to the tubes. In the other case, brazing material is placed between the sleeve and tubes, as shown in the sketch, and then heat is applied which causes the brazing material to flow and form a brazed connection.

FIGURE I

Welding Method

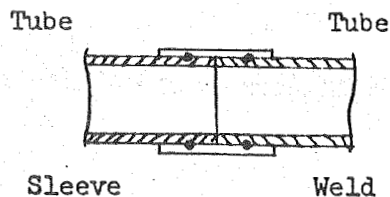


FIGURE III

Brazing Method

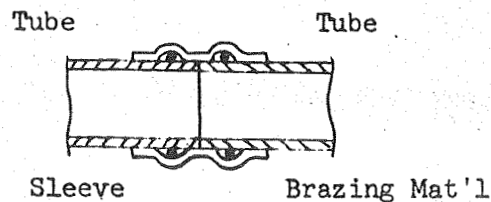
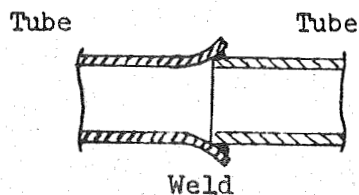


FIGURE II

Welding Method



Present Method

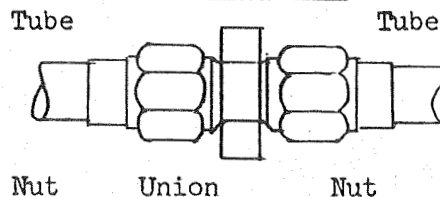


Table 3-5 presents the preliminary weight data on possible weight savings if the present line break connections are eliminated by "in place" welding. For a description of present type of connector and more detailed data, refer to the January 1965 Weight Control Status Report, SM-46949.

TABLE 3-5

PRELIMINARY LINE BREAK CONNECTION WEIGHT DATA

<u>Present Type of Connection</u>	<u>Size of Tubing Involved (O.D.)</u>	<u>Present Number of Connections Required</u>	<u>Weight Savings if Connection Eliminated (lb)</u>
VCSO	1-1/2 inch	7	12.6
BSCO	1-1/4 inch	2	6.0
BSCO	3/4 inch	2	3.4
BSCO	1/2 inch	4	4.8
MC	1 inch	8	8.8
MC	3/4 inch	4	3.2
MC	1/2 inch	11	3.2
MC	3/8 inch	1	0.2
MC	1/4 inch	58	8.0
Totals		<u>97</u>	<u>50.2</u>

3.17 Item 15 - Cryogenic Repressurization

This item consists of replacing a repressurization system using ambient helium (ambient helium repressurization), to provide for orbital restart pressurization, with a system using cold helium heated by a $\text{LO}_2\text{-LH}_2$ Burner that is operated by cryogenic propellants (cryogenic repressurization). The $\text{LO}_2\text{-LH}_2$ Burner exhaust also has a potential application in providing additional thrust for propellant settling during orbital coast.

This design change is accomplished primarily by replacing nine ambient helium bottles with a cold helium bottle and a $\text{LO}_2\text{-LH}_2$ Burner.

These two repressurization systems are schematically illustrated in Figure 3-1.

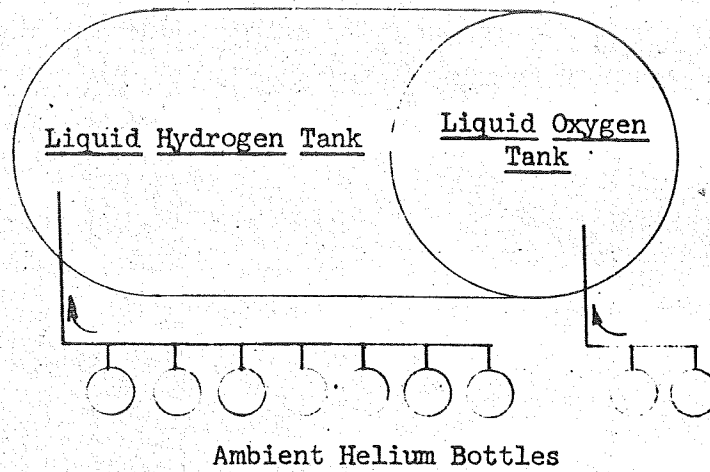
3.18 Item 15A - Structural Modifications for Cryogenic Repressurization

This item incorporates the critical lead-time hardware required to accommodate the cryogenic repressurization system (per ECP X181) which was incorporated at a later date. Stages S-IVB-207 through S-IVB-212 required the addition of two aft dome pads for LH_2 and LOX feed-throughs. Stages S-IVB-503 through S-IVB-506 needed, in addition to the aft dome pads, LH_2 and LOX feed-throughs, cold helium bottle feed-throughs and strap attachments, a LH_2 feed duct aerodynamic fairing, fairing insulation and support installation, and an extension of the auxiliary tunnel.

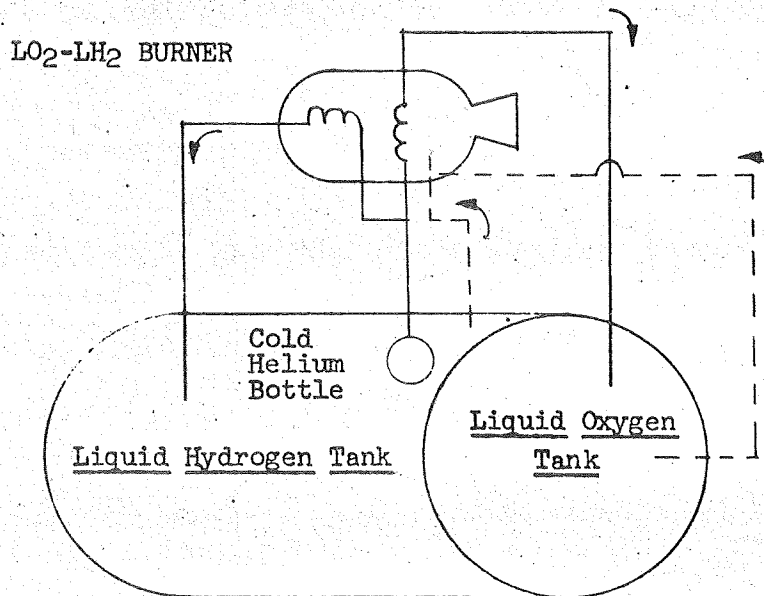
3.19 Item 16 - Trajectory Optimization

This item investigates flying a more efficient vehicle attitude history during first stage flight, with present design limitations being considered, to determine potential increases in payload capability. This is as opposed to the present design ground rule of ballistic (zero angle of attack) flight during first stage operation followed by optimization of the upper stage flight profile.

AMBIENT HELIUM REPRESSURIZATION SYSTEM



CRYOGENIC REPRESSURIZATION SYSTEM



Legend

- Helium
- Cryogenic Propellant

Figure 3-1. Repressurization Systems

3.20 Item 17 - Operational Telemetry

This item is accomplished through the utilization of the decreased telemetry (TM) requirements of an operational stage as compared to a research and development (R&D) stage. The weight savings were primarily the result of the following design changes:

- 1) Deletion of the R&D instrumentation not required for the operational vehicle.
- 2) The reduction in TM from five sets (one SS/FM, three PAM/FM/FM, and one PCM/FM) to one set (PCM/FM).
- 3) Deletion of two antennas and one tape recorder not required on operational vehicles.
- 4) Redesign of the thermo-conditioning system.

3.21 Item 18 - Decreased Chem-Milling Tolerances

It was discovered through extensive measuring of chem-milled dome segments that the average skin thickness continually exceeded the nominal gage. This average thickness was determined from an overall high point to low point spread of about seven mils. It is proposed that the upper tolerance limit of ten mils be reduced to five mils, thereby lowering the overall spread down by at least two and one-half mils which would also decrease the average skin thickness by the same amount. Note that the overall spread is assumed to remain constant at seven mils. This change is incorporated by reducing the tolerance from $\begin{smallmatrix} +.010 \\ -.005 \end{smallmatrix}$ to $\pm .005$ on the forward dome, aft dome, and common bulkhead skins. The weight saving is dependent upon the number of segments prior to this change that are already within the new tolerance of $\pm .005$ inch.

3.22 Item 19 - Thermo-Conditioning Panel Improvement

This item proposes that the existing aluminum sheets and channels be replaced by "Lockalloy", an alloy of 68 percent beryllium and 32 percent aluminum. Also, the HT-424 adhesive now used is to be replaced by XB-124 adhesive.

Table 3-6 presents the weight data for this item. The weight totals are based on 6 panels being affected.

TABLE 3-6

THERMO-CONDITIONING PANEL WEIGHT DATA

<u>Part Number</u>	<u>Description</u>	<u>Present Weight (lb.)</u>	<u>Proposed Weight (lb.)</u>	<u>Weight Savings (lb.)</u>
1A98128-1	Plate	13.0	10.5	2.5
1A98131-1	Plate	13.4	10.6	2.8
1A98129-1	Plate	58.8	44.4	14.4
1A98123-1	Channel	5.9	4.4	1.5
1A98124-1	Channel	5.9	4.4	1.5
1A98124-2	Channel	5.9	4.4	1.5
1A98125	Fitting	2.6	2.0	0.6
- - -	Adhesive	10.4	7.4	3.0
Totals		115.9	88.1	27.8

3.23 Item 20 - Aluminum Tubing and Fittings for the Hydraulic System

This item considers the use of aluminum instead of steel tubing and fittings for the low pressure side of the hydraulic system.

3.24 Item 21 - Use of Lighter Weight Material in Hydraulic System Accumulator

This item proposes replacing the steel parts of the accumulator with a lighter weight material. Three such materials considered are titanium, aluminum and beryllium. Since the characteristics of titanium are similar to steel, that change would be a material substitution only. However, if aluminum or beryllium are used, the parts would have to be beefed-up or redesigned. The expected weight saving using beryllium is presented in Table 3-7.

TABLE 3-7

ACCUMULATOR-RESERVOIR WEIGHT DATA

<u>PRESENT CONFIGURATION</u>			<u>PROPOSED CONFIGURATION</u>	
<u>Part Number</u>	<u>Description</u>	<u>Weight (lb.)</u>	<u>Description</u>	<u>Weight (lb.)</u>
1A78643	Piston	4.8	Upper Housing	6.0
1A78644	Piston	2.3	Lower Housing	8.7
1B29312	Housing	17.9	Accumulator Piston	3.0
1A83316	Sleeve	5.4	Reservoir Piston	1.3
1A83359	Vent Tube	0.5	Reservoir Cap	1.7
1A83362	Housing	13.8		
1A83363	Piston	3.1		
1A83361	Cap	4.5		
1A89339	Bolts	1.6		
<u>Total</u>		53.9		20.7

Weight Savings = $53.9 - 20.7 = 33.2$ pounds

3.25 Item 22 - Material Substitution for Propulsion System Tubing

Substantial weight savings may be realized by substituting aluminum in lieu of steel for some of the propulsion tubing. Preliminary weight data are presented in Table 3-8.

3.26 Item 23 - Wire Weight Reduction

The S-IVB has numerous applications in which 24, 26, or 28 gage conductor material with less insulation than now used would satisfy the present electrical characteristics requirements. Larger gage (20 or 22) conductors with heavy insulation are now being used in order to meet mechanical property (i.e., tensile strength and abrasion resistance) needs.

TABLE 3-8

PROPOSED PROPULSION TUBING CHANGES

			<u>Weight (lb)</u>		
			<u>Steel</u>	<u>Aluminum</u>	<u>Weight Savings</u>
A. <u>S-IVB/IB</u>					
<u>Drawing Affected</u>	<u>Proposed Changes</u>				
1A66894 Engine Instl	1/2 O.D.x.028 Steel to 1/2 O.D.x.042 Alum.		1.4	0.7	0.7
1A39325 Pneu I, LOX Tank	1/2 O.D.x.058 Steel to 1/2 O.D.x.095 Alum.		10.1	5.3	4.8
1A39325 Pneu I, LOX Tank	1/2 O.D.x.049 Steel to 1/2 O.D.x.083 Alum.		4.5	2.5	2.0
1A39325 Pneu I, LOX Tank	1/2 O.D.x.028 Steel to 1/2 O.D.x.042 Alum.		1.4	0.7	0.7
1A39325 Pneu I, LOX Tank	3/4 O.D.x.049 Steel to 3/4 O.D.x.065 Alum.		2.5	1.2	1.3
1A39325 Pneu I, LOX Tank	3/4 O.D.x.028 Steel to 3/4 O.D.x.049 Alum.		1.5	0.9	0.6
1A39325 Pneu I, LOX Tank	1-1/4 O.D.x.049 Steel to 1-1/4 O.D.x.083 Al.		7.8	4.5	3.3
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.065 Steel to 1-1/2 O.D.x.095 Al.		3.3	1.7	1.6
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.049 Steel to 1-1/2 O.D.x.083 Al.		4.4	2.6	1.8
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.035 Steel to 1-1/2 O.D.x.065 Al.		24.1	15.5	8.6
Total			61.0	35.6	25.4
B. <u>S-IVB/V</u>					
1A66894 Engine Instl	1/2 O.D.x.028 Steel to 1/2 O.D.x.042 Alum.		1.4	0.7	0.7
1A39325 Pneu I, LOX Tank	1/2 O.D.x.058 Steel to 1/2 O.D.x.095 Alum.		11.7	6.2	5.5
1A39325 Pneu I, LOX Tank	1/2 O.D.x.049 Steel to 1/2 O.D.x.083 Alum.		3.2	1.8	1.4
1A39325 Pneu I, LOX Tank	1/2 O.D.x.028 Steel to 1/2 O.D.x.042 Alum.		1.4	0.7	0.7
1A39325 Pneu I, LOX Tank	3/4 O.D.x.028 Steel to 3/4 O.D.x.049 Alum.		3.2	1.9	1.3
1A39325 Pneu I, LOX Tank	1-1/4 O.D.x.049 Steel to 1-1/4 O.D.x.083 Al.		7.8	4.5	3.3
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.065 Steel to 1-1/2 O.D.x.095 Al.		3.3	1.7	1.6
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.049 Steel to 1-1/2 O.D.x.083 Al.		8.1	4.7	3.4
1A39326 Pneu I, LH ₂ Tank	1-1/2 O.D.x.035 Steel to 1-1/2 O.D.x.065 Al.		24.1	15.5	8.6
Total			64.2	37.7	26.5

This wire weight reduction technique proposes that the existing wiring be replaced by improved wiring of reduced gage and insulation which still satisfies both electrical and mechanical characteristics requirements. These improvements are possible through the application of high strength conductor material, improved stranding methods for conductors and improved conductor insulation methods.

In addition to the improvements, the design requirements for existing conductors will be reviewed for possible gage reductions.

It has been estimated that 70 percent of the presently used 22 gage wire in the instrumentation systems could be replaced by 24 or 26 gage with no adverse effect on electrical performance. Weight savings by using 24 or 26 gage in place of 22 gage would be 42 percent and 58 percent, respectively. For the estimated 200 pounds of 22 gage wire on the S-IVB assuming equal quantities of 24 and 26 gage substitution, this would amount to a savings of 70 pounds.

3.27 Item 23A - Size Reduction of Copper Wire in E/E Equipment

This item proposes to reduce the wire size from 22 to 26 gage for signal and low power circuitry within Electrical/Electronic equipment (black boxes). The mechanical and current carrying capacity of 22 gage hookup wire exceeds that which is required for use inside the E/E equipment.

The weight reduction possible through implementation of this item is approximately 7 pounds to the stage dry weight, resulting in a payload increase of 7 pounds.

3.28 Item 24 - Welded Module Package Redesign

This item proposes to reduce the weight of Electrical/Electronic Welded modules. This can be done by utilization of a new and smaller double-pole, double-throw relay, which will permit a reduction in the size of the whole module.

The weight savings depends upon the amount of each of the various modules used on the stage. Table 3-9 gives a breakdown for S-IVB-207 and S-IVB-504.

TABLE 3-9

WELDED MODULE PACKAGING REDESIGN WEIGHT DATA

Part Number	Description	Weight Saving per Module (lb)	S-IVB-207		S-IVB-504	
			No Mod.	Total Savings	No Mod.	Total Savings
1A82274	Temp. Bridge	0.14	40	5.6	44	6.2
1A98088	Temp. Bridge	0.11	5	0.6	5	0.6
1A74211	2 Amp. Relay	0.19	9	1.7	9	1.7
TOTAL			54	7.9	58	8.5

3.29 Item 25 - Electrical Bus Connector Redesign

This item proposes a change to a vendor designed bus connector. This change provides the brazing of the interconnecting copper leads within the connector with this area potted and flush with the rear of the connector, thus reducing the size of the bus connector encapsulation material.

The present method utilizes soldering and welding for the connector inter-connecting leads outside the connector and therefore requires more encapsulation material.

The vendor redesigned bus connector can be mounted directly on the support panel. This will provide additional weight reduction by eliminating some of the present hat section support bracketry.

Preliminary weight data are presented in Table 3-10.

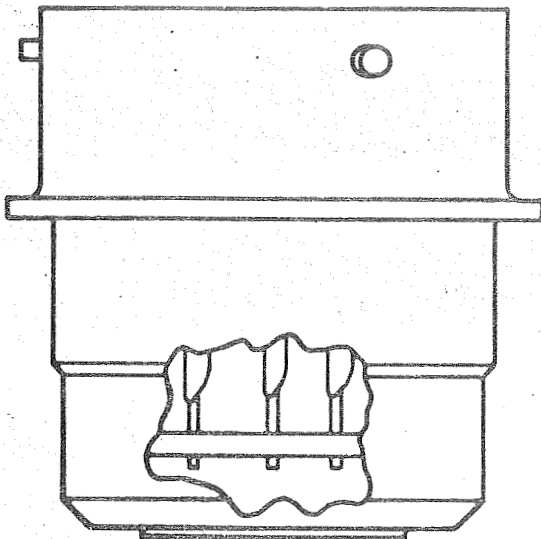
The following is a typical comparison sketch, not necessarily of a true design, showing the present design and the proposed design.

TABLE 3-10

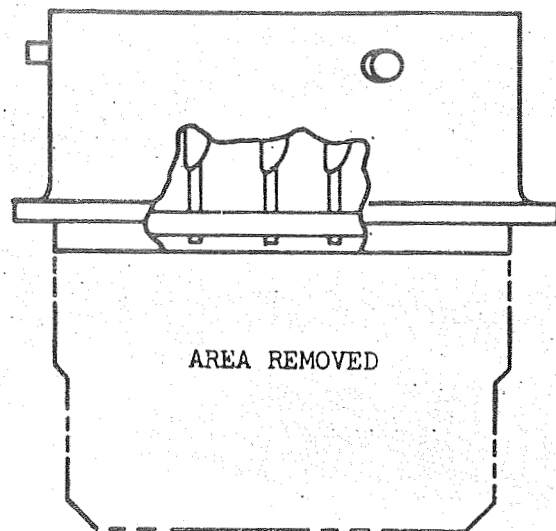
ELECTRICAL BUS CONNECTOR REDESIGN WEIGHT DATA

PART NUMBER	DESCRIPTION	NO. OF CONN. PER VEHICLE	WT SAVING PER CONN.	TOTAL WEIGHT SAVINGS
55-9204	Shorting Plug	1	.04	.04
1A84576	Module, Bus Conn.	18	.10	1.80
1A84577	Module, Bus Conn.	5	.32	1.60
1A84579	Module, Bus Conn.	1	.03	.03
1A93522	Module, Bus Conn.	1	.34	.34
1A96707	Module, Bus Conn.	34	.15	5.10
1A97868	Module, Elec. Distr.	56	.02	1.12
1A98042	Module, Bus Conn.	4	.30	1.20
1B40619	Module, Bus Conn.	1		
1B29862	Module, Bus Conn.	4	.01	.04
(Redesigned Bus Connector Totals/Stage)		(125)		(11.27)
1A96461	Bracket	2	.60	1.20
1B28162	Bracket	1	.50	.50
(Eliminate Hat-Section Support Bracketry Totals/Stage)		(3)		(1.70)
			Totals/Stage	12.97

PRESENT DESIGN



PROPOSED DESIGN



3.30 Item 26 - Use of Color-Coded Hookup Wire

This item proposes a change to the wiring inside electrical/electronic equipment that provides a color-coded hookup wire in lieu of a black plastic tubing with a number stamped on it, placed over each wire end.

This will eliminate cost, weight, fabrication time, and installation of the black identification tubing. Also, this method will facilitate the wiring installation and require less space in the black box.

Approximately 4,450 wires and 8,455 pieces of tubing are involved per stage.

The weight saving would amount to approximately 7 pounds/stage.

3.31 Item 27 - Miniaturized Instrumentation System

This item proposes replacing conventional circuits with semi-conductor integrated circuits, or thin film integrated circuits. A substantial weight reduction with no penalty for performance and reliability can be accomplished.

A detailed study for weight comparison between a conventional and a miniaturized T/M (telmetry) system was presented in Appendix 1 of the January 1965 Weight Control Status Report, SM-46949.

3.32 Item 28 - Electrical Wire Clamps

This item proposes that teflon cushioned clamps be replaced by silicate rubber cushioned clamps where temperature requirements permit.

The teflon cushioned clamps require the wire bundle to be wrapped with fiber glass tape along the area in contact with the clamp. The fiber glass tape is used to prevent wire pinching and loose fit of the clamp.

The silicate rubber cushioned clamps are lighter. The ability of the rubber cushion to compress provides for a greater variety of wire cable diameter sizes. This reduces the use of fiber glass tape to a minimum. The silicate rubber also restricts the teflon insulated wire slippage within the clamp. Approximately 4500 clamps are required for S-IVB-201.

3.33 Item 29 - Reduction of Forward Dome Internal Insulation

This item proposes that the internal insulation on the unwetted portion of the forward dome be removed; this area provides a relatively minor source of LH₂ heating. For the S-IVB/IB, this would move the insulation back approximately 80 inches from the forward end. The removal of 500 square feet of insulation would reduce the stage weight by 213 pounds. For the S-IVB/V, the insulation could be taken back about 50 inches from the forward end. The corresponding removal of 187 square feet of insulation would reduce the stage weight by 80 pounds.

3.34 Item 30 - Stringer Redesign on Skirts and Interstage

This weight reduction item proposes that the stringers of the forward skirt, aft skirt, and interstage of both the Saturn S-IVB/V and S-IVB/IB Stages be redesigned to a minimum strength to weight ratio considering present design loads. The proposed redesign would be slanted to maintain existing skins, stringer spacing, and frames. Only the stringer cross section would be changed.

The weight savings for this change is depicted in Table 3-11.

TABLE 3-11

STRINGER REDESIGN WEIGHT DATA

	<u>Saturn IB</u>	<u>Saturn V</u>
Forward Skirt	55 lbs	82 lbs
Aft Skirt	134 lbs	133 lbs
Aft Interstage	N/A	324 lbs

3.35 Item 31 - Redesign of Aft Skirt Air Conditioning Duct

This change would remove the external insulation in the upper portion of the aft dome. The space between frames 241 and 255.25 would be enclosed with a mylar wrapped insulation blanket to form the environmental control duct. It would result in a weight saving of approximately 12 pounds due to reduction in the amount of insulation and adhesive.

Figure 3-2 presents a sketch of the proposed system.

3.36 Item 32 - Chemical Milling of Skin Sections on Skirts and Interstage

This item involves chem-milling the skin sections on the forward and aft skirts and aft interstage to an optimum panel thickness to meet the acoustical and strength requirements of the skin. It represents a design change to nearly all of the skin panels of those structures, and a large change in manufacturing technique of the part.

3.37 Item 33 - Combination Check Valve and Instrumentation Mount - LH₂ and LOX Chillydown Return

This item proposes a redesign of a section of the LH₂ and LOX chillydown return duct assemblies. The present design consists of an aluminum check valve connected to a steel instrumentation mounting tee. The proposed design would combine the check valve and instrumentation mount in a single aluminum housing. The present and proposed designs are shown in Figure 3-3. The estimated weight saving associated with this item is 2.5 pounds per assembly or 5 pounds per stage.

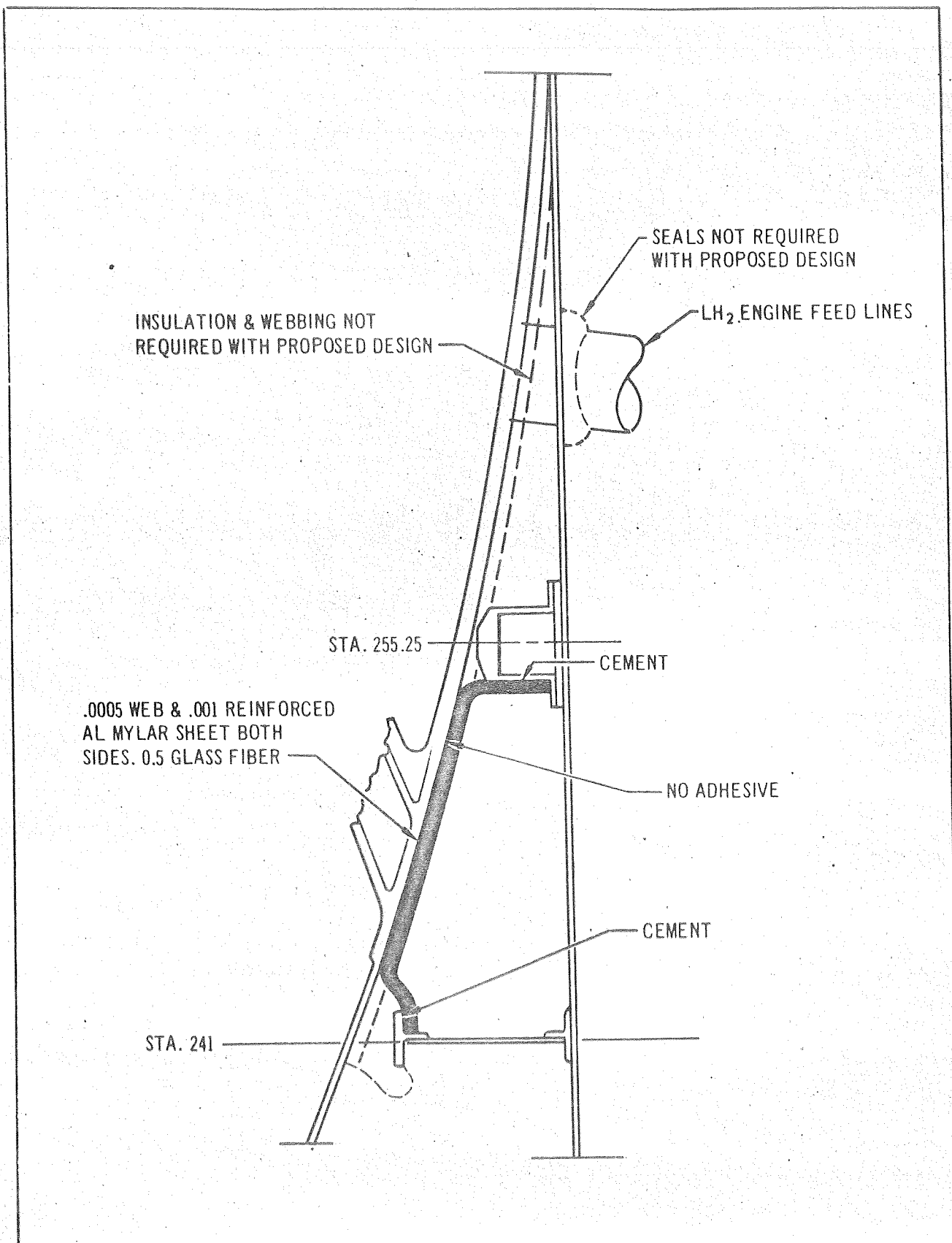
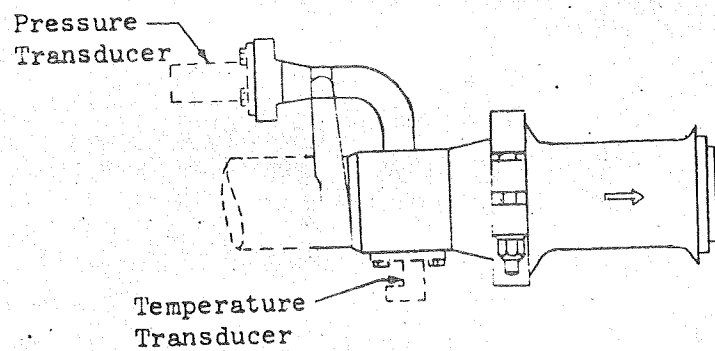
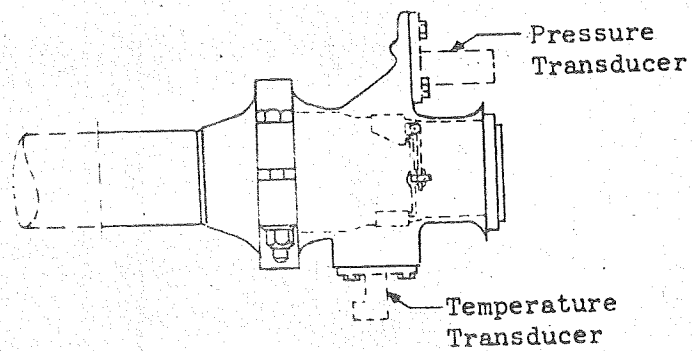


Figure 3-2. Proposed Aft Skirt Environmental System



PRESENT DESIGN



PROPOSED DESIGN

Figure 3-3. Proposed Redesign Combining Check Valve and Instrumentation Mount

3.38 Item 34 - LH₂ Non-Propulsive Vent

The S-IVB/V LH₂ non-propulsive 4 inch vent duct was originally sized for cyclic venting considerations. The S-IVB/IB LH₂ non-propulsive vent duct was sized based upon maximum allowable earth orbit hydrogen tank depressurization time of 15 minutes. For this value, a 4 inch duct was also required. In order to maintain common hardware between S-IVB/IB and S-IVB/V, Propulsion chose to use the 4 inch duct on S-IVB/V when cyclic venting was replaced by the constant pressure continuous venting system. The translunar blowdown time would be extended from 4-1/2 minutes for the 4 inch duct to 8-1/2 minutes for the 3 inch duct - considering a blowdown pressure range of 34 to 8-1/2 psia; this would violate no known requirement.

This item proposes to reduce the weight of the normal vent system on the S-IVB/V by making the following changes.

	<u>Weight Reduction (lbs)</u>
Reduce Duct Diameter from 4" to 3"	-27
Reduce Duct Gage from 0.035" to 0.025"	-7
Replace Pressure Compensated Bellows	-5
Total Change	-39

3.39 Item 35 - Zero Gravity Liquid-Gas Separator

The initial vendor design of the zero gravity liquid gas separator did not appear to meet the specification requirements. Rather than redesign the separator, it was decided to evaluate the possibilities of eliminating it due to the implementation of a constant pressure continuous propulsive vent on the S-IVB/V LH₂ tank.

The constant pressure continuous vent eliminates the blowdown cycle before second burn, which was required to meet the LH₂ pump NPSH requirement. This factor, combined with the settling effects of the propulsive vent, removes the requirement for a liquid-gas separator.

3.40 Item 36 - Alternate Adhesive for the Common Bulkhead

A test program was proposed to establish an alternate adhesive/foam material for the common bulkhead to reduce the weld degradation problem caused by the high temperature cure cycle of the present adhesive/foam material.

The primary goal of the test program was to obtain an adhesive material having low temperature cure requirements suitable for common bulkhead use. However, adhesives with much lower densities than the presently used adhesive were to be tested. If successful, the lightweight adhesive could provide up to a 93 pound reduction.

3.41 Item 37 - Redesign of Common Bulkhead

This item proposes a potential payload improvement resulting from redesign of the common bulkhead. The redesign is made possible by assuming that preconditioning the common bulkhead would eliminate cryogenic shock as a design condition.

The weight reduction would result from a net reduction in common bulkhead face thickness, a reduction in core thickness, and reduction in attach ring material. Preliminary analysis indicates a payload improvement of approximately 203 pounds. A weight breakdown is presented in Table 3.12.

TABLE 3-12

COMMON BULKHEAD REDESIGN WEIGHT DATA

<u>Item</u>	<u>Present Weight</u>	<u>Proposed Weight</u>	<u>Weight Savings</u>
Forward Facing Sheet	268	342	-74
Aft Facing Sheet	416	195	221
Core	314	269	45
Aft Dome Attach Ring	260	249	11
Total	1258	1055	203

3.42 Item 38 - Use of Beryllium-Aluminum Alloy for Skins and Doublers of the Skirts and Interstage

This weight reduction item proposes that a Beryllium-Aluminum alloy, known commercially as "Lockalloy", be directly substituted for the existing 7075 aluminum skins on the skirts and interstages of Saturn S-IVB Stages.

Table 3-13 presents the present weight of existing exterior skins and doublers for both the IB and V Stages. Also presented are the estimated weight savings that could accrue by direct substitution of "Lockalloy" for these structures.

TABLE 3-13

LOCKALLOY SKIN AND DOUBLER WEIGHT SAVINGS DATA

<u>Area</u>	<u>Weight of Existing Skins and Doublers</u>		<u>Weight Savings Using Lockalloy</u>	
	<u>IB</u>	<u>V</u>	<u>IB</u>	<u>V</u>
Forward Skirt	387	401	84	87
Aft Skirt	298	321	64	69
Interstage	936	1285	202	276
Total	1621	2007	350	432

3.43 Item 39 - Redesign Electronic Equipment Mounting Panels

This item proposes that a weight savings is possible by redesigning the aft skirt electronic equipment mounting panels. The redesign includes reducing the face sheet thickness from 0.063 inch to 0.035 inch due to replacing melamine bonded with epoxy bonded fiberglass laminated sheet.

3.44 Item 40 - Redesign Mounting Bridge, Ullage Rocket Fairing Assembly

This item proposes that the weight of the ullage rocket fairing assembly be reduced by redesigning the mounting bridge (Part Number 1A72953-1) so that aluminum could replace steel. This would result in a 2.4 pound dry weight

savings per fairing or a total dry weight reduction of 7.2 pounds and 4.8 pounds for the S-IVB/IB and S-IVB/V Stages, respectively.

3.45 Item 41 - S-IVB/V Aft Skirt Skin Thickness Reduction

Sonic fatigue data from acoustical development testing indicates that an aft skirt skin thickness reduction from 0.040 inch to 0.032 inch is adequate for the allowable acoustical loads. A detailed strength analysis also confirms the structural adequacy of this proposed design change. The weight savings would be approximately 55 pounds.

3.46 Item 41A - S-IVB/V Aft Interstage Skin Thickness Reduction

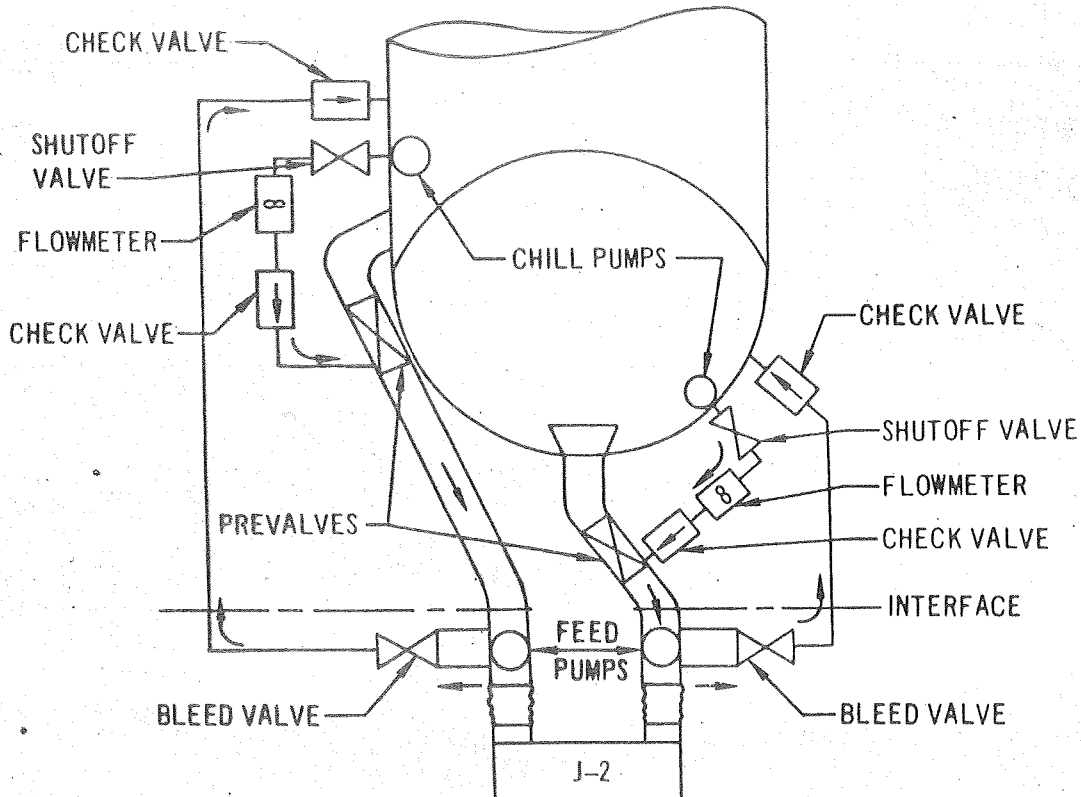
This proposed change is identical to Item 41 except that it is effective on the aft interstage and yields a weight saving of approximately 170 pounds (57 pound payload increase).

3.47 Item 42 - Reverse Flow Engine Chillydown System

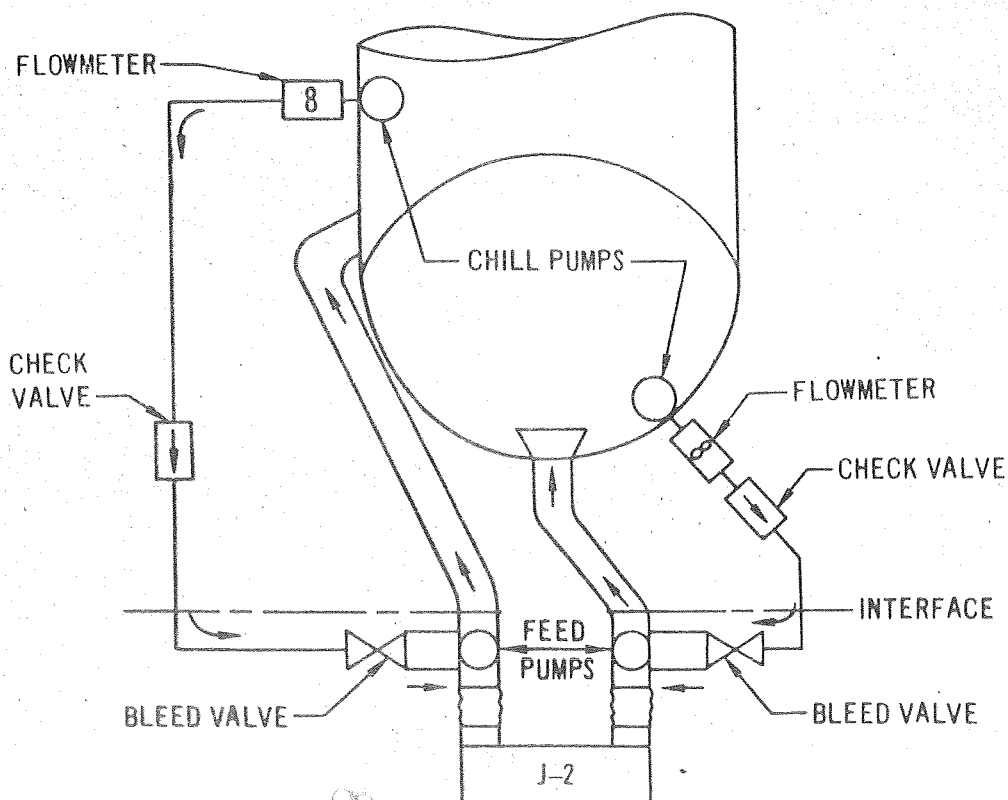
This item proposes to replace the forward flow chillydown system with a reverse flow chillydown system. The forward flow system uses the lower portion of the main propellant feed ducts to supply the J-2 Engine with chillydown propellant, utilizing precheck valves to prevent backflow through the upper portion of the feed ducts. The chillydown propellant is returned to the tanks through the chillydown return lines. The reverse flow system would modify the chillydown lines into feed ducts for the chillydown propellant and then return the chillydown propellant to the tanks through the main feed ducts. This would eliminate the precheck valves and the chillydown bypass lines, which should reduce weight and increase reliability.

A schematic of the existing forward flow and of the proposed reverse flow chillydown systems is presented in Figure 3-4.

The preliminary weight savings data are presented in Table 3-14.



FORWARD FLOW CHILLDOWN INSTALLATION



REVERSE FLOW CHILLDOWN INSTALLATION

Figure 3-4. Schematics of Existing and Proposed Engine Chilledown Systems

TABLE 3-14

REVERSE FLOW ENGINE CHILLDOWN SYSTEM WEIGHT SAVING DATA

<u>Item</u>	<u>Part Number</u>	<u>Number Required</u>	<u>Total Weight (lb)</u>
Existing System:			
Prevalve	1A49968-1	1	35.0
Prevalve	1A49968-503	1	35.0
Pump - LH ₂	1A49421-1	1	13.0
Pump - LOX	1A49423-1	1	13.0
Flow Meter - LH ₂	1A89104-503	1	1.5
Flow Meter - LOX	1A89104-501	1	1.5
Check Valve - Feed Lines	1B53920-1	2	0.4
Shut-off Valve - LH ₂	1A49965-503	1	5.0
Shut-off Valve - LOX	1A49965-505	1	5.0
Check Valve - Return Lines	1A49964-1	2	1.7
Duct Assy. - LH ₂ Bypass	1A49966-501	1	13.0
Duct Assy. - LOX Bypass	1A87740-1	1	8.4
Duct Assy. - LOX Return	1A87736-1	1	19.0
Duct Assy. - LH ₂ Return	1A87738-1	1	18.5
Duct Assy. - LH ₂ Return	1A87741-1	1	7.7
Couplings & Mounts			10.4
Attach Parts, Gaskets, Misc.			<u>10.0</u>
Total Weight of Existing System			199.0
Proposed System:			
Pump - LH ₂	1A49421-1	1	13.0
Pump - LOX	1A49423-1	1	13.0
Flow Meter - LH ₂	1A89104-503	1	1.5
Flow Meter - LOX	1A89104-501	1	1.5
Check Valve - Feed Lines	1B53920-1	2	0.4
Prevalve Replacement Spools		2	22.0
LH ₂ Chilldown Feed Duct		1	40.0
LOX Chilldown Feed Duct		1	12.0
Couplings & Mounts			13.0
Attach Parts, Gaskets, Misc.			<u>10.0</u>
Total Weight of Proposed System			127.3
Net Weight Savings			71.7

3.48 Item 43 - Redesign Transducers and Mating Parts from Conoseal to MC Design

This item proposes to reduce the stage weight by redesigning the temperature and pressure transducers and their mating parts from the present Conoseal design to a MC design.

Each operational stage has approximately 30 transducers which would be affected by this redesign. The weight saving per transducer is approximately 0.4 pounds, which would result in a total weight saving per stage of 12 pounds.

3.49 Item 44 - Elimination of Cold Helium Bottles on S-IVB/IB

The Saturn IB LOX tank pressurization system has eight (8) cold helium bottles mounted in the LH₂ tank. Four (4) are located in the main tunnel area and four (4) in the auxiliary tunnel area. The number of bottles was originally based on a common system with the Saturn V Stage. Analysis has shown that two (2) cold helium bottles could be removed on all Saturn IB flights without degrading the mission reliability.

3.50 Item 45 - Reduction of Retro-Rocket Shock Factor

The design shock factor used on loads applied to the S-IVB Aft Interstage by the thrust of the retro-rockets is based primarily on the rise time to peak load, but also depends upon the natural frequency of the system and an accurately calculated value of the retro-rocket interstage structure spring constant.

The present S-IVB/V Aft Interstage design uses a shock factor of 2.0. For some time, it has been proposed that this factor could be reduced; the shock factor reduction would present a possible weight savings thru redesign of the aft interstage structure.

Results of static testing at Tulsa in July 1965 substantiated the fact that the shock factor could be reduced. The test specimen failed while holding 200 percent of limit load. Limit load in this case included a factor of 2.0 on the 3 rocket thrust value of 44,600 pounds. Failure load was then

about 178,500 pounds, a value 43 percent higher than the design ultimate load of 125,000 pounds. Based upon the same ratio of failure to ultimate load, the ultimate load of 100,000 (corresponding to a shock factor of 1.6) would result in a capability of 143,000 pounds which is still favorable in respect to the design ultimate load.

This item therefore proposes that the retro-rocket shock factor be reduced from 2.0 to 1.6 and the permissible design changes as a result of this be accomplished on the S-IVB/V Aft Interstage. The design changes would involve reductions of the frame cap area on Frames No. 4 through No. 7 (140 pounds), and a gage reduction on the intercostal webs between Frames No. 4 and No. 7 (20 pounds).

The total dry weight savings of this change would amount to 160 pounds and result in a payload gain of approximately 50 pounds.

3.51 Item 46 - LH₂ Cylinder Weight Reduction

Advanced Systems & Technology (AS&T) has been studying a weight optimization redesign of the S-IVB LH₂ cylindrical tank. Investigation included the use of a titanium alloy instead of aluminum. The best efforts to date have resulted in a redesign which would save approximately 481 pounds. The improved design retained aluminum as the material but used biaxial material properties to size the skin thickness and a less conservative buckling analysis for the sidewall design. Redesign considerations omitted the aspect of re-tooling and its relation to the formulation of an economical weight reduction item which could be implemented on the S-IVB. Skin thickness and web thickness and spacing were variables.

Other areas of investigation which could affect the magnitude of weight reduction in the LH₂ cylinder redesign is that the internal insulation may provide strength equal to, or more than, that provided by the ribs.

By a simplification of the cylinder redesign considered in the 481 pound estimate, using skin thickness reduction and leaving the existing web spacing, a majority of the weight savings could be realized. A reduction of 17 mils

(0.143 to 0.126) in skin thickness would result in an approximate weight savings of 360 pounds.

This design change, which would not be optimum, would nevertheless provide a significant weight reduction to the stage, with a minimum of retooling, and provide the earliest effectivity. A material savings due to use of a thinner plate than presently used is also possible.

3.52 Item 47 - Ordnance Thruster Separation System

This item proposes using ordnance thrusters in place of the retro-rockets now used on the S-IVB/IB/V Aft Interstages to affect separation of the lower stage from the S-IVB. This method of separation will make possible a significant weight savings.

The Ordnance Thruster Separation System would be a redesign of the vehicle for a new structural concept, rather than a rework design. The thruster is a cylinder-piston arrangement with a two foot stroke - similar to those used in ejection seat catapults - but specially tailored to the stroke, thrust level and thrust buildup characteristics desired for this separation system. Ordnance material of about 0.4 pounds per thruster, when ignited by means of a confined detonating fuse (CDF) supplies the separation force.

Twelve of these thrusters are spaced around the outer diameter of the aft interstage with the separation force acting on pads mounted on the stage. The non-fixed end of the design will allow excursion of one stage with respect to the other during separation. A minimum force of 380,000 pounds, considering a 10 + 2 "out" thruster configuration will affect separation within existing time requirements.

Table 3-15 reflects the weight savings for one internal and one external arrangement of thrusters for the S-IVB/IB Vehicle - and one, an external arrangement, for the S-IVB/V Vehicle.

TABLE 3-15

THRUSTER SEPARATION SYSTEM WEIGHT DATAS-IVB/IB

<u>Present System</u>	(2156)
Stage	(132)
Retro-Rocket Impingement Curtain	125
Wire Wrap	7
Interstage	(2024)
Attach Structure	442
Retro-Rockets	1502
Impingement Insulation	80
<u>Internal Thruster System</u>	(364)
Stage	
Aft Skirt Modifications	73
Interstage	
Thrusters + Structural Changes	291
Weight Savings (2156 - 364)	(1792)
<u>External Thruster System</u>	(449)
Stage	
Aft Skirt Modifications	86
Interstage	
Thrusters + Structural Changes	363
Weight Savings (2156 - 449)	(1707)

TABLE 3-15 (Cont'd)

THRUSTER SEPARATION SYSTEM WEIGHT DATAS-IVB/V

<u>Present System</u>	(2075)
Stage	(132)
Retro-Rocket Impingement Curtain	125
Wire Wrap	7
Interstage	(1943)
Attach Structure	160
Retro-Rockets	1502
Impingement Insulation	60
Structure Beefup	221
<u>External Thruster System</u>	(355)
Stage	
Aft Skirt Modifications	48
Interstage	
Thrusters + Structural Changes	307
Weight Savings (2075 - 355)	(1720)

3.53 Item 48 - Passive Thermo-Conditioning System

This item proposes replacing the present active thermo-conditioning system (cold plates) for the forward skirt electronics with a passive system. Where the active system uses a temperature controlled fluid circulating through channels in the electrical equipment mounting panels (cold plates), the passive system takes advantage of the operational wattage of the "black" boxes and proper location of cold critical and hot critical items to obtain temperature control. Honeycomb panels and shockmounts, similar to the cold

plates but without the integral heat exchanger, would be used for mounting the equipment. The passive system would be designed for operation in space, where thermal radiation is the primary mode of heat transfer. Since the active system thermo-conditions the electronics both on the ground and in space - going to a passive system would require an additional ground thermo-conditioning system. A manifold for ducting a gaseous nitrogen purge would be appropriate.

A preliminary weight trade-off for a passive system on the S-IVB operational stages appears in Table 3-16, which shows a net weight savings of 70 pounds.

TABLE 3-16

THERMO-CONDITIONING FORWARD SKIRT ELECTRONICS

Present System - "Active"		189 lbs.
Panels 5 at 25 lbs.	125	
Piping Installation	35	
Thermo-Conditioning Fluid	29	
Proposed System - "Passive"		119 lbs.
Panels 5 at 16 lbs.	80	
Ground Thermo-Conditioning System	39	
Weight Savings		70 lbs.

3.54 Item 49 - Relocation of Cold Helium Bottles on S-IVB/IB

This item proposes an alternative to the positioning of the six cold helium bottles on the S-IVB/IB. When the reduction from eight to six bottles was approved (Reference: Item 44 - DAC Achievements), two configurations had been studied; three bottles on each tunnel, and four on one tunnel - two on the other. Subsequent analysis revealed that all six bottles could be mounted in one tunnel without appreciably affecting the usable helium supply

or degrading mission reliability. Up to six mounting pads are available on both the auxiliary and the main tunnels. Location of all six bottles on the main tunnel would eliminate the need for the auxiliary tunnel, cross over pipe assemblies, and supporting bracketry. A dry weight savings of approximately 30 pounds would be realized.

3.55 Item 50 - Surface Finish Change on S-IVB/V

This item proposes that external surface finishes for the S-IVB/V liquid hydrogen tank be investigated for a payload gain by reducing LH₂ boiloff (during a 4.7 hour mission) up to J-2 engine restart. By a proper choice of surface finish to achieve a better combination of solar absorptivity (α) and emissivity (ϵ), a significant reduction in boiloff (up to 25 percent) is possible.

The present boiloff rate and the continuous vent system provide about a 6 pound thrust for propellant settling during orbital coast - this is a minimum design requirement. A reduction in boiloff is possible, however, due to the incorporation of LO₂-LH₂ Burner (of the Cryogenic Repressurization System) which could provide 16 to 25 pounds of thrust throughout orbital coast.

The best practical surface finish for reducing heat input to the LH₂ may therefore be chosen. Table 3-17 depicts a number of surface finish possibilities and an estimate of the payload to be gained. In most cases, an increase in stage dry weight will result.

3.56 Item 51 - Air Spring Separation System

This item proposes using an air spring in place of the retro-rockets now used on the S-IVB/IB and S-IVB/V Aft Interstages to affect separation of the lower stage from the S-IVB. This method of separation would make possible a significant weight savings in addition to eliminating undesirable features of the retro-rocket separation system.

TABLE 3-17

PAYLOAD GAINS THROUGH SURFACE FINISH CHANGE

Surface Finish				Heat Input Btu (10) ⁻³	Decrease In Heat Input Btu (10) ⁻³	Decrease In Boiloff lb.	Payload Increase Due to Less Boiloff lb.	Change In Stage Dry Weight lb.	Net Payload Increase lb.
Type	Weight (lb.)	α	ϵ						
Normal White Paint - 1 coat	33	.33	.9	595	---	---	---	---	---
Normal White Paint - 3 coats	61	.27	.9	564	31	163	70	28	42
Best White Paint - 3 coats	61	.21	.92	533	62	326	140	28	112
Aluminum Paint - 1 coat	33	.28	.22	515	80	421	181	-0-	181
Aluminum Tape	102	.20	.10	457	138	726	312	69	243
Aluminized Mylar Tape	46	.20	.05	452	143	753	324	13	311
LMSC Optical Solar Reflec- tor Paint	42	.05	.81	441	154	811	349	9	340

The air spring system would put to use the latent potential energy of residual ground purge GN_2 to provide the separation force. The present design allows the purge gases to be vented at a rate which will minimize the differential pressure across the interstage skin. This idea proposes programming a residual pressure at lower stage thrust decay; the severing of the tension strap at the S-IVB Aft Interstage field splice by action of the mild detonating fuse would then initiate S-IVB/lower stage separation. Preliminary calculations indicate that a pressure of about 3.4 psig for the S-IVB/V and 7.3 psig for the S-IVB/IB would be required. Lower pressures would be sufficient if a retainer curtain were used to contain the gas for a portion of the separation event.

There are a number of advantages to this system other than weight reduction: it would not be prone to a thrust unbalance as would happen with retro-rocket separation under a "one out" situation (which is a design requirement); it would eliminate surface finish degradation resulting from the retro-rocket exhaust, this degradation may account for as much as 800 pounds increased LH_2 boiloff and at the same time preclude or jeopardize the implementation of Item 50, which proposes a surface finish change that would reduce boiloff by about 800 pounds; it would provide additional payload capabilities due to both impulse to the stage at separation and a reduction of vehicle drag through removal of the retro-rocket protuberances; it would provide additional structural integrity, reduce acoustic loads, and provide an inert atmosphere in the interstage which would reduce chances of combustion or an explosive gas mixture.

The beneficial weight savings would be the result of removing the retro-rockets and fairings, redesign of the structure because of retro-rocket removal, and removal of structural insulation, thrust structure wire wrap, and flame shield curtain for the aft skirt electronics which are protection against damage from retro-rockets' plume impingement. The total dry weight savings is depicted in Table 3-18. The resulting net gain in payload capability would be approximately 754 and 429 pounds for the S-IVB/V and S-IVB/IB, respectively.

TABLE 3-18

AIR SPRING SEPARATION SYSTEM WEIGHT DATA

	<u>S-IVB/IB</u>	<u>S-IVB/V</u>
<u>Present System</u>	(2206)	(2117)
Stage	(132)	(132)
Retro-Rocket Impingement Curtain	125	125
Wire Wrap	7	7
Interstage	(2074)	(1985)
Attach Structure 298 + 144	442	160
Retro-Rockets	1502	1502
Impingement Insulation	80	60
Structural Beefup	-0-	221
Ordnance & Support Installation	50	42
<u>Air Spring System</u>	(45)	(45)
Stage	-0-	-0-
Interstage		
Pressure Control System	45	45
Weight Savings	(2161)	(2072)

3.57 Item 52 - Reliability Approach to Structural Design Factors

The foundation of this item is the anticipated over conservativeness of a design based upon an arbitrary factor of safety. Vehicle reliability is a contractual criteria that part of the vehicle reliability assignable by math model to all structures is .99985. If, however, the present design factors result in a structure which is .999999... reliable, then we have found an area for potential weight savings.

Application of statistical distribution and probability of simultaneous occurrence of a finite number of structural design loading influences would establish the design criteria. Areas for analysis would be the probability

of exceeding certain ground wind "loads", flight wind loads", in-flight dynamic loads and thermal environments. Statistical methods may also be used partially or totally in analysis methods and procedures, structure allowables and structural testing.

Actualization of this approach is not straight forward, however; some of the following items are areas for deliberation. There is at present inadequate statistical background for current structural concepts - hence, the need for a significant increase in full scale structural testing.

Salvage operations would involve a complicated consideration of the effect on the original statistical model. Negotiations would be required to change load analysis techniques for critical phases of flight (Customer controlled). A long lead time is required for this type of analysis resulting in either schedule delay or late implementation effectivity and the costs involved in redesign. Each structure must be handled on an individual bases and even a structure shown to be extremely efficient may have to be compromised to provide additional stiffness necessary for control stability or to avoid poorly defined flutter or acoustic excitation boundaries.

Nevertheless, a typical section of major structure is being investigated using the reliability approach. The most vulnerable design factor likely to fall as a result of this study is the use of an ultimate factor of safety. In many cases, structural components are designed by ultimate failure criteria although the structure may perform at limit load well below yielding. The determination of an over conservatively designed structure (by a reliability approach) would permit either structure redesign with increased stresses (and an attendant weight savings) or payload gains through greater mission flexibility allowing the use of more optimum trajectories which would increase design loads to the extent allowed by structural reliability criteria.

I N D E X

<u>Sequence</u>	<u>Month</u>	<u>Report Number</u>
	<u>1964</u>	
1	November	SM-46845
2	December	SM-46911
	<u>1965</u>	
3	January	SM-46949
4	February	SM-47026
5	March	SM-47084
6	April	SM-47175
7	May	SM-47208
8	June	SM-47237
9	July	SM-47283
10	August	SM-47334
11	September	SM-47369
12	October	SM-47394
13	November	SM-47425
14	December	SM-47495
	<u>1966</u>	
15	January	SM-51815
16	February	SM-51859
17	March	SM-51898

I N D E X (Cont'd)

<u>Sequence</u>	<u>Month</u>	<u>Report Number</u>
	<u>1966</u>	
18	April	SM-51358
19	May	SM-53211
20	June	DAC-56320